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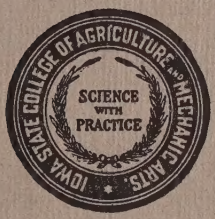

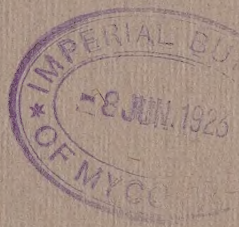

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By I. E. Melhus, J. C. Gilman, and J. B. Kendrick

The foundation for potato seed disinfection was well laid by the early work of Bolley (3) and Arthur (2), but development of this subject has not kept pace with the advancement of knowledge in other phases of disease control. Both of these authors advised a long soaking of the tubers in comparatively weak solutions, and their recommendations stand practically unchanged up to the present time.

The chief limitations of this method are its laboriousness and the variable results obtained. In an earlier publication the authors of this bulletin (13) described a method of seed treatment that eliminates the long soak and in addition makes it possible to practice seed treatment rapidly by machinery. The causes of the variable results obtained have been studied for the past three years in the laboratory and field.

The work presented in this bulletin attempts to open up this field of investigation and supply data bearing on the toxic action of formaldehyde and the influence thereon of concentration of the solution, of temperature of treatment and of duration of exposure. The data is limited to two organisms, *Actinomyces scabies* and *Rhizoctonia solani*, as they occur on the surfaces of potato tubers. Both laboratory and field work were carried on, altho the latter was limited due to the time required to get results and the non-controlled external factors which influence such results.

The report of the work is grouped as follows: (1) Laboratory studies on the effect of formaldehyde on the common scab organism. (2) Laboratory studies on the effect of formaldehyde on *Rhizoctonia solani*. (3) The effect of formaldehyde on the germination of potato tubers. (4) Field data, comparing hot formaldehyde treatment with the standard treatments as a control measure for (*a*) common scab, and (*b*) black scurf. (5) The effect of standing and heating on the strength of formaldehyde solutions.

While no data are available on the fungicidal value of formaldehyde, a large amount of work has been done on its toxic action on a related group, the bacteria.

Ever since Loew (11) discovered the germicidal effect of formaldehyde, work in the field has been accelerated. It was soon recognized that the temperature at which the organisms

were exposed to the action of formaldehyde had a marked influence on the rapidity of its toxic action.

Pottevin (16), as early as 1894, studied the germicidal effect of this substance on *Bacillus anthracis*. He dried his organisms on pieces of linen and after immersing them in the solutions at various temperatures, either grew them on suitable media or inoculated them into guinea pigs.

When the spores of *Bacillus anthracis* were immersed for two hours in a two percent solution of formaldehyde at 15°C., the spores were not killed. However, when the temperature was raised to 35°C. for two hours, the spores were killed; one hour at this temperature was not sufficient to kill all the spores. At 52°C., the spores were killed after one hour, but not after five minutes exposure. A comparable hastening of the action of formaldehyde by the raising of the temperature was found when a 15 percent solution was used. Again, with a 42 percent solution, the time of exposure necessary to kill the spores of this organism was shortened when higher temperatures were employed. The behavior of the bactericide was the same when spores of *B. anthracis* were replaced by spores of *B. subtilis*.

Lassablière (10) in his extensive studies summarizes his results as follows*: "De leur ensemble il résulte que:

1° La pénétration est nulle avec une température inférieure à 10°.
2° Elle commence à être manifeste entre 10° et 18°.
3° Elle est suffisante entre 18° et 30° pour assurer une désinfection efficace des locaux, des meubles et des tissus qui peuvent les recouvrir.
4° Elle est absolue entre 50° et 60° et permet une désinfection complète des matelas et objets de literie."

Anderson and McClintic (1) make this general statement regarding the influence of temperature on the toxic action of formaldehyde: "It is a well-known principle in the use of disinfectants that, within certain limits, the higher the temperature at which the disinfectant is used the greater its germicidal properties. This increase in germicidal properties of disinfectants thru the influence of heat is not the same for all disinfectants; some, such as formaldehyde, are more strongly influenced than others."

It would seem logical on theoretical grounds that fungous spores should respond in the same way as bacteria to formal-

* "The results show that:
1. There is no penetration at a temperature lower than 10° C.
2. The penetration begins to appear between 10° and 18° C.
3. An effective disinfection of places, furniture and fabrics which may cover it, is assured between 18° and 30° C.
4. The disinfection of matresses and bedding is absolute between 50° and 60°C."

dehyde at higher temperatures. A survey of the literature reveals the fact that neither formaldehyde nor any other fungicide has been studied or used at high temperatures.

Melhus, Rosenbaum and Schultz (14), working for the control of the powdery scab of potatoes in Maine, found that the most effective treatment in controlling this disease was a solution of formaldehyde, two pints in 30 gallons of water at 46-50°C. for five minutes. With this method they got only 1.20 percent of the tubers infected, while the standard method of seed treatment, formaldehyde one pint in 30 gallons of water, gave 2.85 percent diseased tubers, and mercuric chloride, four ounces in 30 gallons of water for 1½ hours, gave 2.83 percent diseased tubers. In a later paper Melhus (12) reported that a solution of formaldehyde, two pints in 30 gallons of water at 48-50°C. for five minutes was effective in controlling common scab on potatoes, while a temperature of 55°C. showed some injury to the germination of the seed tubers.

THE FUNGICIDAL ACTION OF FORMALDEHYDE ON ACTINOMYCES SCABIES

The fungicidal action of formaldehyde was first studied in the laboratory. Tubers infested with common scab were treated in strengths of formaldehyde solutions at varying temperatures and durations of exposure.

Arthur (2) first recommended the use of formaldehyde for the control of common scab of potatoes. His treatment consisted of soaking the potatoes for two hours in a solution made of one pint of 40 percent formaldehyde solution added to 30 gallons of water. This formula is still in common use.

In 1900 Jones (6), recognizing that this method was cumbersome and time consuming, tried to improve upon it by the use of formaldehyde gas in the storage cellar. While the results reported the first year were very favorable, later work done in conjunction with Edson (8) and Morse (9) gave very variable results, altho Morse (15) later perfected the method and recommends its use when large quantities of potatoes are to be treated. He, however, recognizes that this method is likely to injure the seed and warns the user of this danger.

Stewart and Gloyer (22) investigated the reasons for injury to tubers subjected to formaldehyde gas and concluded that the quantity of potatoes treated, the humidity of the air in the fumigation room and the state of dormancy of the tubers are the chief factors contributing to the injury. They found that injury occurred where less than 12 pounds of potatoes per cubic foot of air space were used.

Stewart and Gloyer's conclusions are in accord with what we should expect, considering the chemical properties of formaldehyde. It is a well-known fact that formaldehyde is most active in a saturated atmosphere at relatively high temperatures, 50-60°C. The condition of moisture and temperature in storage quarters vary widely, thus the inconsistency of the gaseous treatment.

Melhus (12), modified the original method by strengthening the solution, raising the temperature at which the treatment was made and shortening the time of exposure.

The efficiency of these different methods of treatment in controlling *Actinomyces scabies* was tested in the laboratory, and the results of this study are here reported.

LABORATORY STUDIES

In the laboratory method used, the potatoes infected with the potato scab organism were treated in different ways, as shown later, and subsequently isolations were made to determine whether the organisms had been killed. For this purpose the method of isolation described by Shapovalov (21) was found most convenient.

The tubers used in these studies were Early Ohios grown in South Dakota in 1918, and held in storage at Ames, Iowa. The tubers were quite generally infected with scab and served as an excellent source of material. Tubers were selected that showed two or more scab sori of as nearly the same size and appearance as possible. These were cut into two pieces, with a scab sorus on each piece. One piece was treated and the other used as a check and subsequently isolations were made from each piece.

The treatments were made as follows: After heating the formaldehyde solution up to the desired temperature, the half-tubers to be treated were placed in a small cotton bag and placed in the solution, care being taken that the temperature remained at the desired point during the time the tubers were immersed. If the treatment called for covering afterward, the tubers were left in the bag in which they had been treated. After drying, the isolations were made from the treated and untreated pieces as indicated above.

All plates were held at room temperatures and examined after 72 hours. The colonies of *Actinomyces scabies* usually could be recognized by this time by the characteristic discoloration of the medium around them, tho in a few cases such discoloration did not occur. The colonies were always circular, very tough, with a characteristic glistening surface. After three to four days, the cretaceous surface growth began to

appear at the center of the colonies and rapidly increased in diameter as the media began to dry. Where the discoloration did not occur, a careful examination of the other characteristics was made, together with microscopic examination. Counts were made after the plates had developed sufficiently to establish beyond doubt the identity of the organism. This was usually done after three to four days. The treatments used and the results obtained are recorded in table I.

Summary of Table I: Table I gives the data from 610 plates poured from scab sori treated for various lengths of time with different concentrations of formaldehyde and at various temperatures. An equal number of plates was made from the untreated scab sori on the same tubers as checks. Two plates were poured from each scab sorus. In order to get a basis for comparison of the different treatments, the percentage of check plates for each treatment was raised to 100 percent, and on this basis the percent of plates from the treated tubers that showed no colonies was calculated. These figures are given under the heading "Percent Control." Two facts are outstanding; first, in only two of the 22 treatments were all the organisms in the treated sori killed, and second, in the untreated plates, all the sori did not contain viable organisms or else these were killed by the surface sterilization before the plates were poured.

From the standpoint of toxicity of the solution, the data show that the formaldehyde solution (1-120) at 50°C., for one minute and covered thirty minutes and sixty minutes, respectively, was more toxic to *Actinomyces scabies* than the same solution at 5-6°C., for two hours. At the higher temperature the control percents were 80 and 83 respectively, while with the lower temperature and longer immersion the control percent was 73. On the other hand the toxicity of the formaldehyde solution (1-120) for two and one-half minutes at 50°C., and covered thirty minutes, was approximately the same as that for the same solution at 5-6°C., for two hours, that is, 75 and 73 percent control, respectively. Mercuric chloride (1-1000) at 23-28°C., for ninety minutes approximated this same degree of control with a percentage of 73.

The toxicity varied with the time of exposure, the temperature and the time the tubers were covered after the treatment. Little difference is shown between dipping the tubers into the solution and the one minute treatment. In these instances a weighted average of all the plates poured from the dip treatment gives 78.5 percent of the plates free from the scab organisms, while 61.0 percent of the plates from the one minute treatments remained free. That these averages do not entirely show the true relation of these treatments is apparent when the figures

TABLE I.—FUNGICIDAL ACTION OF FORMALDEHYDE ON *ACTINOMYCES SCABIES* AT VARIOUS LENGTHS OF TIME, CONCENTRATION, AND TEMPERATURES

Fungicide	Concentration	Temp.	Time in minutes		Treated			Checks			Percent Control	
			Dipped	Covered	No. plates	No. colonies	Percent plates with colonies	No. plates	No. colonies	Percent plates with colonies	Colonies	Plates
CH_2O	1-120	50°C.	‡		80	65	11.2	80	7649	70.	99.2	84
CH_2O	1-120	50°C.	‡	15	46	63	19.5	46	5667	73.9	98.9	74
CH_2O	1-120	50°C.	‡	30	30	9	20.	30	1193	63.3	99.3	69
CH_2O	1-120	50°C.	‡	60	26	3	7.7	26	827	70.7	99.7	81
CH_2O	1-120	50°C.	1	Dried	82	291	44.	82	19583	86.6	98.5	50
CH_2O	1-120	50°C.	1	15	22	10	31.8	22	2352	72.7	99.6	57
CH_2O	1-120	50°C.	1	30	18	4	11.1	18	1712	55.5	99.8	80
CH_2O	1-120	50°C.	1	60	30	5	13.3	30	568	73.3	99.1	83
CH_2O	1-120	50°C.	2.5	Dried	30	96	23.3	30	5107	88.6	98.2	74
CH_2O	1-120	50°C.	2.5	15	30	18	20.	30	494	60.	96.4	66
CH_2O	1-120	50°C.	2.5	30	30	23	16.6	30	527	66.6	95.7	75
CH_2O	1-120	50°C.	2.5	60	38	0	0.	38	2851	63.2	100.	100
CH_2O	1-120	50°C.	5	Dried	10	0	0.	10	460	80.	100.	100
CH_2O	1-120	50°C.	5	30	10	6	30.	10	3001	80.	98.	63
CH_2O	1-120	5-6°C.	120		20	6	20.	20	1789	75.	99.7	73
CH_2O	1-120	10°C.	120		10	2	10.	10	414	60.	99.5	84
CH_2O	1-120	20°C.	120		10	1	10.	10	789	80.	99.9	88
CH_2O	1-240	5-6°C.	120		20	12	25.	20	1398	70.	99.2	65
CH_2O	1-240	10°C.	120		10	1	10.	10	320	10.*	99.7	0
CH_2O	1-240	20°C.	120		28	8	14.3	28	1640	73.9	99.5	81
$HgCl_2$	1-1000	23-28°C.	90		20	9	20.	20	3071	75.	99.7	73
Water		50°C.	1		10	2428	80.	10	2745	80.	8.8	0

* All check plates discarded except one, badly contaminated.
‡ Dip was momentary.

from which they come are considered individually. The reason for the disparity of the averages is the high toxicity found when the dip without covering was used; 84 percent of the plates were free from the organism. That this figure is too high is obvious when we consider that the one minute and two and one-half minute treatments gave only 50 and 74 percent, respectively, of the plates free. Except for this discrepancy we find that there was a gradual increase in the toxicity of the solution at 50°C. as the time of exposure was lengthened, the weighted average for the four series, dip, one minute, two and one-half minutes and five minutes, being 78.5 percent, 61 percent, 80.0 percent and 81.5 percent, respectively. Of these the average for the one minute treatment is too low, that of the dip too high, while that of the five minute series is based on too few platings.

The effect of temperature on the toxicity of formaldehyde is best shown in the series of two hour treatments with formaldehyde 1-120. At 5-6°C., 20 plates were poured and 73 percent of them remained free from the scab organism.. At 10°C. with ten plates, 84 percent remained free and at 20°C. with ten plates, 88 percent were clean.

The greater effect of the stronger solution is exemplified when this series of 40 plates (1-120) is compared with the similar series with the 1-240 solution. The former gave 79.5 percent of the plates free from *Actinomyces scabies,* while the latter gave but 61.5 percent.

That covering the tubers after treatment aids toxicity is shown in both the one and two and one-half minute treatments. In the former, no covering gave more than 50 percent clean plates, fifteen minute covering gave 57 percent clean, thirty minute covering gave 80 percent and sixty minute covering, 83 percent. Similar figures are found in the two and one-half minute treatment; not covered, 74 percent; fifteen minute covering, 75 percent, and sixty minute covering, 100 percent. This series is not as good, probably because of the limited number of plates poured, 158 plates in the one minute series and 128 in the two and one-half minute series.

Altho the data presented show certain irregularities and discrepancies, due in part, doubtless, to the inadequate number of trials, yet it is clear that formaldehyde at high temperatures for short periods of time is as toxic as when used at low temperatures for longer periods. It is also quite apparent that surface disinfection is seldom complete, which may well be an important factor in the interpretation of varying results obtained by different investigators. Still further, it is quite plain that when the temperature, concentration of the fungicide and

and duration of the treatment are varied, the toxic action of formaldehyde is materially influenced.

FIELD EXPERIMENTS FOR CONTROL OF COMMON SCAB

The effectiveness of formaldehyde and mercuric chloride, both hot and cold, was tried further in the field. The first series of experiments was made in 1916 and continued to date. In 1918, however, the plants on the plots were so badly injured with hail and excessive rain that no data were taken.

Summary of Table II: In 1916 three lots of scabby Irish Cobblers were treated in three different ways: standard formaldehyde method, mercuric chloride method, and hot formaldehyde method. In the latter case the following formula was used: two pints of formaldehyde in 30 gallons of water held at 48-50°C. for five minutes. Two lots, one scabby and another clean, were held as checks. The clean tubers were selected out of the same bin from which the scabby ones were secured. In the fall the scabby tubers were separated out when the crop was harvested and the progeny weighed. Any tuber that showed a scab sorus was classified as scabby. This was a much more rigid classification than is practiced by the grower and should be taken into consideration when interpreting the results reported in table II.

The amount of scab obtained on this lot of clean tubers would rather suggest that they were infested. Of course it may well be that the percent of scab secured in this case was due to soil infestation. In order to determine the source of this infection on the clean checks, a lot of clean seed should have been treated; however, this was omitted. It is significant to note in this set of trials that the scabby checks showed 55 percent scab and the

TABLE II.—POTATO SEED TREATMENT FOR CONTROL OF COMMON SCAB IN 1916

Exp. No.	Variety	Seed	Fungicide	Temp.	Dilution	Time	No. hills	Results				
								Clean tubers in ozs.	Scabby	Total	Yield per hill in ozs.	Percent scab
1	Cobbler	Scabby	CH_2O		1-240	2 hrs.	74	416	44	460	6.2	11.
2	Cobbler	Scabby	$HgCl_2$		1-1000	1½ hrs.	80	544	88	632	7.9	12.5
3	Cobbler	Scabby	CH_2O	48-50°C.	1-120	5 min.	122	860	104	964	7.9	8.
4	Cobbler	Scabby	Check				129	540	432	972	7.5	55.
5	Cobbler	Clean	Check				134	976	144	1120	8.3	12.5
6	Rural	Scabby	$HgCl_2$	48-50°C.	1-500	5 min.	141	832	80	912	6.4	9.
60a*	Rural	Scabby	$HgCl_2$	50°C.	1-1000	5 min.	134	604	72	676	5.0	10.
67a*	Rural	Scabby	Check				66	72	292	364	5.5	81.

* 60a and 67a were grown in a different field in adjoining parallel rows.

treated lots from 8 to 12.5 percent. The hot formaldehyde proved the most efficient under the conditions of this experiment, as shown in table II. It is believed that some of the infection obtained in the three different treatments resulted from soil infestation.

The two lots, 60a and 67a, were grown on a piece of new land that had been recently cleared and had grown only one crop of potatoes previously. The two lots, one treated with hot corrosive sublimate and the other held as a check, were planted in adjoining rows. The treated lot showed 10 percent scab infection, while the check gave 81 percent. Under ordinary field conditions the 10 percent scab secured in the treated lot would have gone on the market without being noticeable to the dealer or consumer; however, it was recorded and charged up against the treatment as an index of its efficiency. The yield data is too limited to warrant making any general statements further than to point out that mercuric chloride and formaldehyde at 50°C. for five minutes did not reduce the yield.

Summary of Table III: In 1917 two bushels of scabby Early Ohios were divided into four lots and treated as shown in table III. In addition, two lots of clean tubers were held as checks, one of which was treated by the standard formaldehyde method, while the other received no treatment. In the former case there developed 6.5 percent infection, while in the latter 22.8 percent showed common scab infection. The tubers treated with the hot formaldehyde solution showed 17.6 percent scab, while those receiving the standard formaldehyde treatment showed 22.9 percent scab. Hot mercuric chloride gave 9.68 percent scab. Again it is clearly evident that mercuric chloride and formaldehyde at 50°C. for five minutes are as efficient as fungicides as when these chemicals are held at lower temperatures and the pathogen exposed for a longer time.

TABLE III.—POTATO SEED TREATMENT EXPERIMENTS FOR THE CONTROL OF COMMON SCAB, 1917

Seed	Fungicide	Dilution	Temp.	Time	Sets planted	Results		Average yield per hill, ounces	Percent scab.
						Clean ounces	Scab. ounces		
Infected	CH_2O	1-240	Cold	2 hrs.	118	218	65	3.36+	22.9
Infected	CH_2O	1-120	48-50°C.	5 min.	126	355	76	3.8	17.6
Infected	Check				130	238	296	4.58+	55.4
Clean	Check	1-240		2 hrs.	183	643	45	3.90	6.5
Infected	$HgCl_2$	1-500	48-50°C.	5 min.	133	522	56	4.6 +	9.68
Clean	Not treated				139	448	133	5.4 +	22.8

Summary of Table IV: In 1919 the field experiments on common scab were made at Ames, Iowa, in order to determine the relative efficiency of different treatments. In each case the various lots were treated and then cut to one eye. The seed was planted in parallel rows with 200 pieces to each row. There were three checks, consisting of clean and scabby potatoes untreated and clean potatoes treated. The checks were spaced approximately every six rows in the plot. Counts were made when the plants began to break thru the ground in order to find the effect of the various treatments on the stand. A

TABLE IV.—RESULTS OF SEED TREATMENT FOR POTATO SCAB IN 1919

Exp. No.	Condition of seed	Fungicide	Temp.	Dilution	Time	Covered	Results		
							Total yield ozs.	Scabby	Percent Scabby
1	Clean						340	48	14
2	Infected						470	58	12
3	Clean	$HgCl_2$		1-1000	1.5 hrs.		584	134	23—
4	Infected	CH_2O	6-8°C.	1-120	.5 hrs.		680	216	32—
5	Infected	CH_2O	6-8°C.	1-120	1 hr.		696	48	7—
6	Infected	CH_2O	6-8°C.	1-120	2 hrs.		772	26	3
7	Infected	CH_2O	20°C.	1-120	.5 hrs.		744	176	24—
8	Infected	CH_2O	20°C.	1-120	1 hr.		648	48	7+
9	Infected	CH_2O	20°C.	1-120	2 hrs.		758	54	7+
10	Clean						742	130	18+
11	Infected						652	320	49+
12	Clean	$HgCl_2$		1-1000	1.5 hrs.		732	212	29—
13	Infected	$CuSO_4$	6-8°C.	3-400	2 hrs.		748	108	14+
14	Infected	$HgCl_2$	6-8°C.	1-1000	.5 hrs.		624	112	18—
15	Infected	$HgCl_2$	6-8°C.	1-1000	1.5 hrs.		776	120	15+
16	Infected	CH_2O	6-8°C.	1-240	.5 hrs.		576	196	34+
17	Infected	CH_2O	6-8°C.	1-240	2 hrs.		736	112	15+
18	Clean						736	240	33—
19	Infected						624	240	38+
20	Clean	$HgCl_2$		1-1000	1.5 hrs.		680	68	10
21	Infected	CH_2O	48-50°C.	1-120	5 min.		668	165	25—
22	Infected	CH_2O	48-50°C.	1-120	2.5 min.		680	302	44+
23	Infected	CH_2O	48-50°C.	1-120	1 min.		674	242	45—
24	Infected	CH_2O	48-50°C.	1-120	mom.		756	116	15+
25	Infected	CH_2O	48-50°C.	1-60	2 min.		600	196	33—
26	Infected	CH_2O	48-50°C.	1-60	2 min.	1 hr.	640	144	23—
27	Infected	CH_2O	48-50°C.	1-60	2 min.	5 hrs.	596	224	38—
28	Clean						620	130	21—
29	Infected						832	236	36—
30	Clean	$HgCl_2$		1-1000	1.5 hrs.		680	116	17+
31	Infected	CH_2O	48-50°C.	1-120	mom.	30 min.	838	118	21+
32	Infected	CH_2O	48-50°C.	1-120	2 min.	1 hr.	844	200	23+
33	Infected	CH_2O	48-50°C.	1-120	2 min.	2 hrs.	704	72	10+
34	Infected	CH_2O	48-50°C.	1-120	2 min.	5 hrs.	832	192	23
35	Infected	CH_2O	48-50°C.	1-120	2 min.	10 hrs.	664	146	22—
36	Clean						628	144	23—
37	Infected						592	192	32
38	Clean	$HgCl_2$		1-1000	1.5 hrs.		732	86	12—
39	*Infected	CH_2O	48-50°C.	1-120	2 min.	1 hr.	604	100	14—
40	*Infected	CH_2O	6-8°C	1-240	2 hrs.		744	128	17+
41	*Infected	CH_2O	6-8°C.	1-240	.5 hrs.		580	136	23+
42	Clean						596	208	35—
43	Infected						816	160	20—
44	Clean	$HgCl_2$		1-1000	1.5 hrs.		624	116	18+

* Soaked for 24 hours in water previous to treatment.

discussion of this data follows in a later chapter. At harvest time the progeny in each treatment was separated into two lots, scabby and clean, and weighed. The piece of ground used had been under cultivation for many years. For several years it was used as a nursery, but during the preceding four years it was used for school gardens and certain corn experiments. Altho this land had not been used for potatoes within two years, it had grown several crops of potatoes at one time or another.

The best control was with the formaldehyde solution 1-120 for two hours at 6-8°C., which gave only 3 percent of scabby tubers. Formaldehyde solution 1-120, 6-8°C., for one hour and at 20°C. for one and two hours respectively, gave 7 percent scab; while formaldehyde 1-120, 48-50°C. for two minutes, covered two hours, gave 10 percent scabby tubers. Formaldehyde 1-240 for two hours at 6-8°C. gave 15 percent scabby tubers and mercuric chloride 1-1000 for one and one-half hours at 6-8°C. also gave 15 percent scabby tubers. The checks showed that there was considerable variation in the soil infestation thruout the field.

From the point of view of the toxicity of the fungicide used, the data confirm that which was found in the laboratory. In the formaldehyde series, the data show that the stronger the solution, the greater is the toxicity. This is especially striking at the low temperature. If the formaldehyde solution 1-240 at 6-8°C. is compared with the 1-120 solution at the same temperature, it is seen that the amount of scab present is reduced, both with the thirty minute treatment and the two hour treatment when the stronger solution is used. In the first instance the reduction is but 2 percent, while in the latter case it is 12 percent. If the latter series were not consistently lower, the difference of 2 percent of scab would perhaps not be signigicant, but when considered with the other data its value as a differential is enhanced. At 48-50°C., the data is not so consistent as to the relative toxicity of different concentrations of the solution. The treatment with formaldehyde solution 1-120 for two and one-half minutes gives 11 percent more scabby tubers than the 1-60 strength for two minutes at the same temperature, but the two minute treament when covered one hour gives the same amount of scab with both the 1-120 and the 1-60 solutions, while in the two minute treatment, covered five hours, the plot treated with the stronger solution gave 14 percent more scabby tubers. This seems to be one of those instances which, with our present limited knowledge of field conditions, is unexplainable.

The effect of covering the tubers after treatment on the whole was to reduce the amount of the scab in the field, for in all

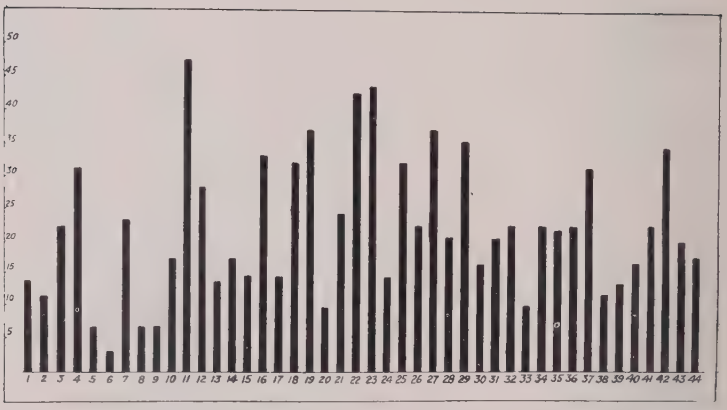

Fig. 1. The percent common scab present on the progeny in the different treatments and checks. The numbers below each histograph refer to the row numbers described in table IV. The heighth of the histograph indicates the percent scab.

the plots where covering was practiced the percentage of scabby tubers is less than in those where no covering was practiced; however, an examination of the data shows that there was more scab present where the seed was covered five and ten hours respectively than where the covering was but one or two hours. To give the figures, when the formaldehyde solution 1-120 at 48-50°C. for two and one-half minutes, without covering, was used, 44 percent of scab was found on the progeny. The same concentration of solution at the same temperature for two minutes and covered one hour gave 23 percent scabby progeny; covered for two hours, 10 percent scab; for five hours, 23 percent scab, and for ten hours, 22 percent scab.

Presoaking the tubers in water for twenty-four hours did not materially affect the treatment. In the three plots in which it was practiced, two gave better results, but the third was poorer.

Summary of Fig. 1: The comparative efficiency of the various treatments is represented graphically in fig. 1. As a whole the treated seed gave less scabby progeny than did the untreated. Of the 26 treatments used, only six gave more scab than the untreated infected checks and two of these were within the limit of error. The same six are the only treatments that had more scab than the mean of untreated clean checks. Only half (14) of the treatments had more scab in the progeny than the clean treated checks. The six treatments mentioned above were: Formaldehyde 1-240 at 6-8°C. for thirty minutes with 34 percent of scab; formaldehyde 1-120 at 6-8°C. for thirty min-

utes with 32 percent of scab; formaldehyde 1-120 at 48-50°C. for one and two and one-half minutes not covered, with 44 and 39 percent of scab respectively; formaldehyde 1-60 at 48-50°C. for two minutes not covered and two minutes covered five hours, with 33 and 38 percent of scab respectively. All six of these treatments gave less scab than the poorest non-treated infected check, which gave 49 percent of scabby potatoes. Nevertheless, they indicate that the thirty minute treatment at low temperature is not good practice and that with the 48-50°C. treatment, covering the tubers after the dip should be practiced in order to insure the greatest good from the treatment.

From the data presented it would seem that the hot formaldehyde solution 1-120 at 50°C. and covered, was as effective in controlling *Actinomyces scabies* in the field as the standard methods recommended in the past. This is especially true when the field and laboratory data are taken together as a basis upon which to draw conclusions.

We notice also that none of the treatments were absolute, i. e., in no case did the treatment wholly eliminate scab, which is in accord with the facts shown in the laboratory data on toxicity of formaldehyde to *Actinomyces scabies*.

Summary of Fig 2: In this case the checks are represented graphically. The mean of the infected seed not treated was 30.2 ± 3.3 percent scab; that of the clean seed not treated 24.0 ± 2.1 percent scab and that of the clean treated checks 18.1 ± 1.81 percent scab. The presence of scab on the clean treated checks shows that the organism was also present in the soil. This is especially significant when we consider that the amount of scab on the clean checks varied in different parts of the plot. The best row in this series showed 10 percent of scab, while the poorest showed 29. Therefore, in interpreting the real

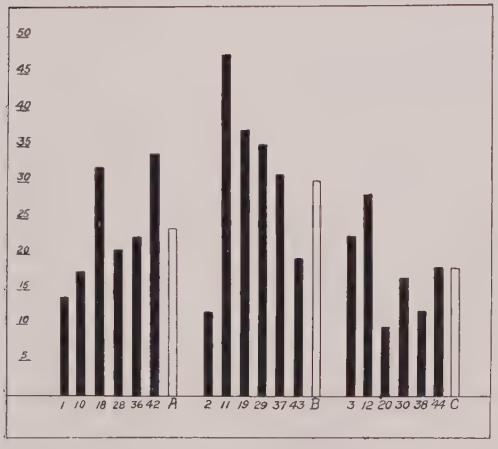

Fig. 2. The percent of the progeny of the check rows showing scab, with the calculated mean. Group A shows the clean untreated check; group B the infected untreated check and group C, the clean treated checks. The height of the columns gives the percent of scabby tubers in each row.

significance and efficiency of the various treatments, this amount of soil infestation should be considered. The clean untreated checks averaged *21* percent scab, while the clean treated showed an average of *18* percent. The difference, 6 percent, was introduced on the clean seed. The variation in scab on the scab-infected checks should also be noted. This varied from *12* to *49*, with a mean of *31.1* percent. It should be recalled in this connection that the amount of infection was constant on the seed.

There are, then, at least three factors that should be considered in any field data on the effect of seed treatment: the soil infestation, the organisms on the healthy surfaces of the seed, and the organisms in the diseased areas. These variables may be estimated by the use of proper checks.

Summary of Table V: In order to summarize the results of this work with common scab, the results of the treatments and checks which were used in all three years have been brought together in Table V. No attempt was made to duplicate all the experiments each year. A comparison of the efficiency of hot and cold formaldehyde and mercuric chloride from year to year was the basis of experimentation. The hot formaldehyde treatment used was the 1-120 solution for five minutes at 50°C., with no covering after treatment. This plot gave rather a high percentage of scabby progeny in 1919, but, nevertheless, over the three years that the experiments were tried this treatment gave practically the same control of common scab as did the cold formaldehyde 1-240 for two hours. The two minute exposure, when coupled with covering after treatment, was more adequate thruout all the plots in 1919 than was this treatment. Therefore, it seems clear that the hot formaldehyde is as good a control measure as the former standard formaldehyde treatment.

It was attempted at the outset to carry hot mercuric chloride thru a series of years, but this seemed futile because of excessive injury induced to the seed. It had no place, therefore, in the 1919 series. The standard mercuric chloride for two years gave 13.75 percent scab, which is slightly less than in the for-

TABLE V.—COMPARATIVE EFFICIENCY OF SEED TREATMENTS IN 1916, 1917, AND 1919

Condition of seed	Fungicide	Temp.	Dilution	Time	No. hills			Percent scab			Mean.
					1916	1917	1919	1916	1917	1919	
Infected	CH_2O	48-50°C.	1-120	5 min.	122	126	181	8	17.6	24.7	16.7
Infected	CH_2O	cold	1-240	2 hrs.	74	118	200	11	22.9	15.	16.3
Infected	None				129	130	1117	55	55.4	31.6	47.3
Infected	$HgCl_2$	48-50°C.	1-500	5 min.	141	133		9	9.68		9.34
Clean	None				134	139	1139	12.5	22.8	25.	20.1

maldehyde trials. Considering that this average is based on two trials rather than three, its reliability is more questionable.

Summary of Fig. 3: The results of the various seed treatments on *Actinomyces scabies* in the field and in the laboratory in 1919 are brought together graphically for comparison. The solid histographs represent the field data, the outlined graphs the laboratory data. The field data is given in percent scab per row, the laboratory data in percent of plates showing colonies in the treatment.

Examination shows that in eight of the eleven cases where comparison is made, the percent scab in the field is less than the percent of plates showing colonies in the laboratory. The exceptions to this condition are all the hot formaldehyde treatments of above two minutes duration. In this group the laboratory data gave a lower percentage of scab on the plate cultures and a higher percentage in the field. Nevertheless, when the relative treatments are considered we find that the 1-120 treatment at 50°C. for one minute showed a greater percentage of scab present in both field and laboratory than did the same treatment for two and one-half minutes or for five minutes. The the two and one-half minute treatment with an additional covering of one hour gave identical percentages with the five minute not covered treatment in both field and laboratory. These graphs show that there is sufficient correlation between the laboratory and the field data to give the laboratory data a distinct value as a prediction of what will happen in the field.

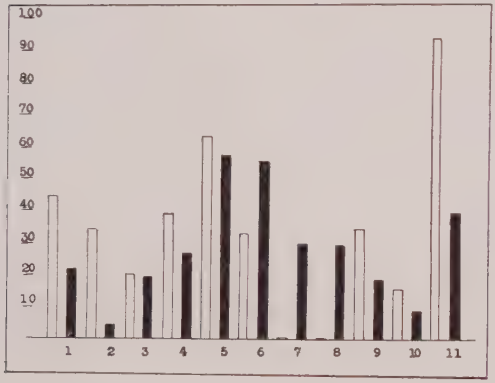

Fig. 3. A comparison of the degree of control in the laboratory and field trials in 1919.
1. Formaldehyde 1-240, 6-8°C. 2 hours.
2. Formaldehyde 1-120, 6-8°C. 2 hours.
3. Formaldehyde 1-120, 48-50 C. momentary.
4. Formaldehyde 1-120, 48-50°C. momentary, covered ½ hour.
5. Formaldehyde 1-120, 48-50°C. 1 minute.
6. Formaldehyde 1-120, 48-50°C. 2½ minutes.
7. Formaldehyde 1-120, 48-50°C. 2½ minutes, covered 1 hour.
8. Formaldehyde 1-120, 48-50°C. 5 minutes.
9. Mercuric chloride 1-1000, 6-8°C. 1½ hours.
10. Formaldehyde 1-120, 20°C. 2 hours.
11. Checks, infected, not treated.

TOXIC ACTION OF FORMALDEHYDE ON THE SCLEROTIA OF RHIZOCTONIA SOLANI

A laboratory test similar to that of the treatment for common scab, was made to determine the efficiency of varying strengths and temperatures of formaldehyde solutions in controlling black scurf, *Rhizoctonia solani*. Before recording the data obtained it may be worth while to summarize briefly some of the most pertinent experimental work relating to black scurf control.

Shortly after the methods of combating potato scab were perfected, black scurf became recognized as a wide-spread and destructive disease that was carried over winter and from field to field by the seed tubers. Almost immediately mercuric chloride and formaldehyde solutions were tried as means of combating the pathogene. In 1902 Rolfts attributed the failure of potato crops in Colorado to the ravages of Rhizoctonia and recommended either formaldehyde or mercuric chloride treatment of the seed as a control measure. Later (17) he published the results of experiments with these solutions and says: "The corrosive sublimate treatment gave marked gains when the treated seed was planted on new ground and the percentage of infected tubers in the crop was much lower. Formalin gave less favorable results, is more expensive and weakens when exposed to the air; consequently it is difficult to keep the solution at standard strength when dipping is done on a large scale."

Selby (19), working simultaneously in Ohio, also tried the comparative value of these two methods in the field, and concludes that the formaldehyde solution gave the more favorable results. In his paper (19) he states: "The warranted conclusion drawn from tests of two seasons with formalin and the extended work of many seasons at the Station with corrosive sublimate appear to be that corrosive sublimate seed treatment does not prevent the Rhizoctonia disease to any appreciable extent, while the formalin seed treatment as shown conspicuously by study of the growing plants and usually in the yields of tubers. does prevent the disease to a very marked extent."

Selby (20) repeated his experiments in the field in 1903, using the formaldehyde treatment 1-240 for two hours as the basis for his work. In his six plots he reports an average reduction of the disease from formaldehyde seed treatment over the untreated checks as 16.8 percent, which he did not compute. This reduction of the disease occurred in all the plots where the seed was treated with formaldehyde. In five of the six plots, he found that the yield was increased over the untreated checks where formaldehyde was used on the seed. From his data

it has been computed that the average increase in yield was 24.5 bushels per acre. In the only plot in which both mercuric chloride and formaldehyde were used (Lot 3), the yield was smaller with the seed treated with either one of these solutions than the yield from the untreated checks. The yield from the tubers in the plot treated with mercuric chloride was less than the yield from those treated with formaldehyde solution. The percent of diseased tubers, however, was also less with the mercuric chloride than with formaldehyde solution. From these facts Selby recommends that "seed potatoes be treated before planting by immersion for two hours in a solution of formalin containing 1 pound of formalin in 30 gallons of water."

In 1912 Güssow (5) also tried out the effect of these two chemicals on the control of Rhizoctonia, using formaldehyde, 1 pint in 30 gallons of water, for three hours and mercuric chloride 1-2000 for three hours. He concludes: "At harvest time it was found that the tubers grown from the 'seed' treated with formalin were almost as badly covered with sclerotia as those originally planted, while those treated with corrosive sublimate were practically clean." No data on yield were given.

Glover (4) studied the effect of formaldehyde (gas and solution) and mercuric chloride by plating sclerotia and untreated tubers on potato agar. His results are summarized in table VI.

In discussing these results the author calls attention to the great variability that occurs when formaldehyde is used as a fungicide for black scurf and concludes that it cannot be used with any degree of certainty for treating seed potatoes. He considers that mercuric chloride was more sure to control this fungus. The small number of sclerotia plated and the lack of adequate controls, except in the gaseous treatments, rather obscure his argument; however, his method of plating the sclerotia treated with mercuric chloride was the probable source of his error.

TABLE VI.—EFFECT OF FORMALDEHYDE AND MERCURIC CHLORIDE ON THE SCLEROTIA OF *RHIZOCTONIA SOLANI*, AS PRESENTED BY GLOVER

Treated Seed						Controls	
			Time	Sclerotia		Sclerotia	
Fungicide	Dilution	Temp.	Dipped	Planted	Percent grew	Planted	Percent grew
CH_2O	gas			973	15.41	734	64.2
CH_2O	1-240	17-22° C.	2 hrs.	327	23.79	...	....
CH_2O	1-240	17-21° C.	24 hrs.	25	0.0	...	....
CH_2O	1-240	19.5° C.	6¾ hrs.	10	0.0	...	....
CH_2O	1-60	21° C.	2 hrs.	60	5.0	...	....
CH_2O	1-20	18° C.	2 hrs.	15	0.0	...	....
$HgCl_2$	1-1000	19-21° C.	1½ hrs.	170	0.0	...	....
$HgCl_2$	1-2000	18-22° C.	1½ hrs.	127	0.0	...	....

METHOD

The laboratory studies concerned with the toxic effect of formaldehyde solutions on black scurf were carried out along lines similar to the studies on common scab. Tubers from the same source (Early Ohios from South Dakota) which showed large numbers of sclerotia on ther surfaces were used.

Solutions of the strength to be tried were heated in a beaker to the desired temperature and the tubers were then suspended in the solution. Care was taken that the tubers should not come in contact with the sides of the container and that the temperature was maintained during treatment. If a large number of tubers were to be treated they were suspended in the solution in a cotton bag. The tubers were dried at room temperatures immediately or covered with a bell jar, where such covering was called for by the experiment. After treatment the sclerotia were removed by means of a flamed scalpel and placed on potato hard agar which had been poured and hardened in a petri dish. These dishes were incubated at room temperature (approximately 20°C.) and observed for growth of the sclerotia after 48 hours. All growth was examined microscopically to check up on the contaminating organisms which might be present. As controls, sclerotia were removed from untreated tubers of the same lot, often from the same tuber before it was treated and plated, in the same way as were the treated sclerotia.

Summary of Table VII: In table VII the toxic action on the sclerotia of black scurf of solutions of formaldehyde 1-60, 1-100, 1-240; mercuric chloride 1-500, 1-1000, 1-2000; copper sulfate 3-400, are compared. The temperature of treatment was varied from 6-8°C. with the thirty, sixty, and one hundred twenty minute exposures to 50 and 55°C. with the one, two and five minute exposures. The effect of covering the tubers after treatment was also considered. Sclerotia from untreated tubers were used as controls in all cases.

From this table certain facts are indicated as to the fungicidal action of formaldehyde and the relation of temperature, time of exposure and strength of solution to the efficiency of the fungicide in controlling Rhizoctonia. First, it must be pointed out that a temperature of 60°C. approaches the thermal death point for Rhizoctonia sclerotia. This is shown by the small percentage of sclerotia that grew after an exposure of five minutes in water at this temperature (1 percent). Water at 50°C. gave only 26 percent of viable sclerotia after five minutes exposure. The one minute water treatment was good at 55°C., where but 16 percent of the sclerotia grew, but practically nil at 50°C., where 78 percent grew.

TABLE VII.—THE TOXIC ACTION OF FORMALDEHYDE UNDER VARIOUS CONDITIONS ON THE SCLEROTIA OF RHIZOCTONIA

Treated Seed							Controls	
			Time		Sclerotia		Sclerotia	
Fungicide	Dilution	Temp. Deg. Cent.	Dipped	Covered	Planted	Percent grew	Planted	Percent grew
CH_2O	1-50	50	1 min.		150	10.8	55	96.3
CH_2O	1-50	50	5 mins.		125	1.6	60	90.0
CH_2O	1-50	55	1 min.		130	10.0	60	96.7
CH_2O	1-50	55	5 mins.		135	1.4	55	94.5
CH_2O	1-50	25	120 mins.		100	.0	70	97.2
CH_2O	1-60	50	2 mins.		50	6.0		
CH_2O	1-60	50	2 mins.	1 hr.	50	4.0		
CH_2O	1-60	50	2 mins.	5 hrs.	50	0.0	50	100.
CH_2O	1-100	50	1 min.		105	34.	105	95.2
CH_2O	1-100	55	1 min.		130	10.	55	95.2
CH_2O	1-100	55	1 min.	12 hrs.	220	6.7	50	84.
CH_2O	1-100	50	5 mins.		145	11.0	80	93.6
CH_2O	1-100	55	5 mins.		400	2.2	100	88.0
CH_2O	1-100	55	5 mins.	12 hrs.	110	4.0	50	84.
CH_2O	1-100	21	120 mins.		15	6.6	15	94.4
CH_2O	1-100	25	120 mins.		100	0.0	70	97.2
CH_2O	1-120	50	mom.		50	2.0	50	98.0
CH_2O	1-120	50	mom.	¼ hr.	80	6.2	80	90.0
CH_2O	1-120	50	mom.	½ hr.	50	16.0	50	100.0
CH_2O	1-120	50	mom.	1 hr.	40	2.5	20	90.0
CH_2O	1-120	50	1 min.		120	8.3	70	98.5
CH_2O	1-120	50	1 min.	¼ hr.	20	0.	10	100.
CH_2O	1-120	50	1 min.	½ hr.	90	13.3	80	98.7
CH_2O	1-120	50	1 min.	1 hr.	50	8.0	50	100.0
CH_2O	1-120	55	1 min.		90	18.8	100	98.0
CH_2O	1-120	55	1 min.	1 hr.	50	18.0	50	100.0
CH_2O	1-120	50	2 mins.		50	24.0	50	100.0
CH_2O	1-120	50	2 mins.	½ hr.	50	20.0	50	100.0
CH_2O	1-120	50	2 mins.	1 hr.	50	8.0	50	100.0
CH_2O	1-120	50	2 mins.*	1 hr.	50	2.0	50	100.0
CH_2O	1-120	50	2 mins.	2 hrs.	100	15.0	50	100.0
CH_2O	1-120	50	2 mins.	5 hrs.	50	0.0	50	100.0
CH_2O	1-120	50	2 mins.	10 hrs.	50	12.0	50	100.0
CH_2O	1-120	50	2½ mins.		40	.0	30	100.0
CH_2O	1-120	50	2½ mins.*	¼ hr.	50	2.	30	90.
CH_2O	1-120	50	2½ mins.	½ hr.	120	5.8	80	90.1
CH_2O	1-120	50	2½ mins.	1 hr.	70	8.5	50	92.0
CH_2O	1-120	50	5 mins.		50	2.0	30	100.0
CH_2O	1-120	50	5 mins.		60	3.5	60	100.
CH_2O	1-120	6-8	30 mins.		50	12.	50	100.
CH_2O	1-120	15	30 min.		40	2.	30	83.3
CH_2O	1-120	20	30 min.		50	12.	50	100.
CH_2O	1-120	15	90 mins.		40	0.	30	83.3
CH_2O	1-120	15	90 mins.		40	2.	30	83.3
CH_2O	1-120	6-8	120 mins.		50	4.	50	100.
CH_2O	1-120	15	120 mins.		40	0.	30	83.3
CH_2O	1-120	20	120 mins.		50	2.	50	100.0
CH_2O	1-120	26	120 mins.		100	6.	50	92.
CH_2O	1-240	6-8	30 mins.		50	32.	50	100.
CH_2O	1-240	6-8	30** mins.		50	2.	50	100.
CH_2O	1-240	6-8	120 mins.		50	0.	50	100.
CH_2O	1-240	6-8	120** mins.		100	16.	50	100.
CH_2O	1-240	10	120 mins.		200	1.	40	95.0
CH_2O	1-240	25	120 mins.		30	0.	30	93.3
CH_2O	1-240	26	120 mins.		100	8.	50	92.0
$HgCl_2$	1-500	9-10	90 mins.		100	18.	50	94.0
$HgCl_2$	1-1000	6-8	30** mins.		50	52.	50	100.0
$HgCl_2$	1-1000	6-8	30 mins.		50	60.	50	100.0
$HgCl_2$	1-1000	20	30** mins.		40	40.	40	90.0
$HgCl_2$	1-1000	6-8	60 mins.		50	64.	50	100.0
$HgCl_2$	1-1000	20	60** mins.		40	17.5	40	90.0
$HgCl_2$	1-1000	6-8	90** mins.		50	4.0	50	100.0

(*) Presoaked 24 hours.
(**) In these experiments the tubers were soaked 24 hours in cold water before being subjected to treatment.

Fungicide	Dilution	Temp. Deg. Cent.	Treated Seed: Time: Dipped	Treated Seed: Time: Covered	Treated Seed: Sclerotia: Planted	Treated Seed: Sclerotia: Percent grew	Controls: Sclerotia: Planted	Controls: Sclerotia: Percent grew
$HgCl_2$	1-1000	6-8	90 mins.		50	40.0	50	100.0
$HgCl_2$	1-1000	10-15	90 mins.		150	6.6	50	86.0
$HgCl_2$	1-1000	15	90*** mins.		80	6.25	40	90.0
$HgCl_2$	1-1000	20	90 mins.		200	10.5	50	98.0
$HgCl_2$	1-1000	6-8	120 mins.		50	50.0	50	100.0
$HgCl_2$	1-2000	15	90 mins.		150	26.6	50	100.0
$CuSO_4$	3-400	6-8	120 mins.		50	58.0	50	100.
H_2O		21	1 min.		5	100.		
H_2O		50	1 min.		50	78.	30	100.0
H_2O		50	5 mins.		65	26. 1	35	100.0
H_2O		55	1 min.		50	16.	20	100.0
H_2O		55	5 mins.		465	2.5	145	91.0
H_2O		60	2 mins.		100	1.	50	84.0
H_2O		60	5 mins.		200	0.5	105	81.0
H_2O		63	5 mins.		100	0.	50	84.0
H_2O		65	2 mins.		150	0.6	105	81.0
H_2O		65	5 mins.		200	0.	105	81.0
H_2O		67	2 mins.		100	0.	50	84.0
H_2O		70	2 mins.		100	0.	50	84.0

The addition of formaldehyde to the solution increased the toxicity, as a rule, so that the time of exposure could be shortened and the temperature lowered to attain the same effect. For example a formaldehyde solution of 1-50 for one minute gave 89.2 percent control, while water at 50°C. for five minutes at the same temperature gave only 73.9 percent.

The longer the exposure the greater the toxic action of the fungicide. This effect is illustrated when formaldehyde 1-120 is used at 50°C. for one and five minutes respectively. The one minute treatment killed 91.7 percent of the sclerotia, while the five minute treatment killed 96.5 percent of the sclerotio. Increased temperature seems to increase the efficiency of the solution; 1-100 at 50°C. for one minute killed 66 percent of the sclerotia treated and with the same treament at 55°C., 90 percent of the sclerotia were killed. Again, with the same solution for five minutes at 55°C., 97.8 percent of the sclerotia were killed, while but 89 percent were killed when the same treatment was made at 50°C.

Exceptions occurred in all of the above cases which are not entirely explainable. Several factors might have influenced these results, such as size of the sclerotium, compactness of the hyphae, or position of the sclerotium on the tuber. Instances were noted, for example, that sclerotia buried in the eye of the tuber were more difficult to kill than those on the open surface. Furthermore, surface disinfection of tubers has its limitations. We need only recall the difficulty encountered in disinfecting the seed coats of grain; naturally, potatoes would be fully as hard to disinfect.

(***) In this case the tubers were soaked only 12 hours.

Presoaking in water did not give uniform results in making the sclerotia more susceptible to fungicides. In some cases, the toxicity was greater where the potatoes were soaked twenty-four hours before treatment, in others there seemed to be no effect. Thus when tubers bearing sclerotia were treated with 1-120 solution at 50°C. for two minutes and covered one hour, 92 percent of these sclerotia were killed, but when the tubers were soaked for 24 hours previous to treatment, 98 percent of the sclerotia were dead. On the other hand, with the 1-240 strength at 6-8°C. for two hours, the effect was opposite. Without the presoak all of the sclerotia were dead; while with it 84 percent were dead.

Covering the potatoes after treatment seemed to increase the toxic action of formaldehyde solutions. This increase was due no doubt to the longer exposure to the formaldehyde gas enclosed by the cover. An illustration of this fact may be noted with the 1-60 solution at 50°C. for two minutes, 6 percent of the sclerotia from the tubers dried immediately after treatment, grew; 4 percent of those covered one hour, and none of those covered five hours.

LABORATORY STUDIES ON THE TOXIC ACTION OF FORMALDEHYDE UNDER FIELD CONDITIONS

The previously described trials were made under laboratory conditions using a small number of tubers. It seemed advisable, therefore, to give consideration to the action of formaldehyde in actual practice. Tubers from lots of potatoes treated just before planting were taken into the laboratory and sclerotia were plated in the same way as previously described. Potatoes from the same lots taken before treatment were used as controls. Lots 1-9 and 15-21 were Early Ohios from the same source as those used in the laboratory. Lot 10 was also Early Ohios, but grown near Ames; Lots 11 and 12 were Irish Cobblers grown in Wisconsin and Lots 13 and 14 were Early Ohios from the same source.

Summary of Table VIII: In the field treatment where larger lots of tubers were treated at one time, the efficiency of the treatment was not as marked as in the laboratory. Heating the solution with a heater such as is described by the authors in a previous publication (13), gave better results on the whole than did steam which was run into the solution.

The low toxicity of the solution heated by means of steam is probably due to the dilution of the solution by the condensation of the steam. This statement is borne out by the fact that Lots 10-14 were all treated in the same solution. Lot 13

TABLE VIII.—THE TOXIC ACTION OF FORMALDEHYDE UNDER FIELD CONDITIONS ON THE SCLEROTIA OF RHIZOCTONIA

Treated Seed								Controls	
Lot	Source of heat	Dilution	Temp. Degree Cent.	Time		Sclerotia		Sclerotia	
				Dipped	Covered	Planted	Per cent grew	Planted	Per cent grew
1	Stove	1-60	52-54	1 min.		110	1.8	25	96.0
2	Stove	1-60	51-53	5 mins.		100	5.0	25	96.0
3	Heater	1-120	50	mom.	15 mins.	55	5.27	50	90.0
4	Heater	1-120	46	1 min.		20	10.0	30	100.0
5	Heater	1-120	47	1 min.	24 hrs. G. H.	50	0.	50	86.0
6	Heater	1-120	52-53	1 min.		50	8.0	30	100.0
7	Heater	1-120	51	1 min.	15 mins.	70	51.0	30	100.0
8	Heater	1-120	52-53	1 min.	15 mins.	40	15.0	30	100.0
9	Heater	1-120	40	1 min.	15 mins.	50	32.0	25	96.0
10	Steam	1-120	48-50	2 mins.		110	29.1	60	100.0
11	Steam	1-120	48-50	2 mins.		110	33.6	100	93.0
12	Steam	1-120	48-50	2 mins.		150	22.3	60	95.0
13	Steam	1-120	48-50	2 mins.		150	7.3	100	99.0
14	Steam	1-120	48-50	2 mins.		150	47.3	60	100.0
15	Heater	1-120	46	5 mins.		50	4.0	30	100.0
16	Heater	1-120	48-49	5 mins.		55	21.0	30	100.0
17	Heater	1-120	51-53	5 mins.		30	56.0	30	100.0
18	Heater	1-120	51-53	5 mins.	15 mins.	30	7.0	30	100.0
19	Heater	1-120	44	5 mins.	60 mins.	40	0.0	30	100.0
20	Heater	1-120	45	5 mins.	60 mins.	50	6.0	30	100.0
21	Heater	1-120	44-49	5 mins.	24 hrs. G. H.	200	0.0	50	86.0

was treated first (only 7.3 percent of the treated sclerotia grew) and Lot 14 last; 47.3 percent of the sclerotia in this lot grew. The strength of the solution was renewed after Lot 11 was treated and Lot 10 shows the effect, for a lower percentage (29.1 percent) of the sclerotia grew from this lot than from Lot 11, where 33.6 percent of the sclerotia remained viable.

In other respects the results in this table do not differ materially from those in the laboratory treatments shown in table VII. It is quite apparent that the results obtained in practice confirm the reliability of the laboratory studies from the standpoint of toxicity.

THE TOXICITY OF FORMALDEHYDE TO *RHIZOCTONIA SOLANI* IN THE FIELD, 1919

In order to check up the laboratory studies on the toxicity of formaldehyde on the sclerotia of *Rhizoctonia solani*, a series of treatments were made with different dilutions of formaldehyde solutions at various temperatures and lengths of exposure, after which the tubers were planted.

Controls consisting of tubers infected with Rhizoctonia with no treatment and apparently clean tubers, not treated, and apparently clean tubers treated with a 1-1000 solution of mercuric chloride at 6-8°C. for one and one-half hours were placed at

approximately each eight rows. In addition infected tubers treated with copper sulfate solution 3-400 for two hours at 6-8°C. and with mercuric chloride 1-1000 for thirty, sixty, ninety and one hundred and twenty minutes were used for comparison.

After treatment the potatoes were cut to one eye and planted in parallel rows, 200 sets per row. The controls were cut and planted in the same way.

The plot of ground on which these experiments were carried out was a comparatively level piece of prairie land, a trifle low at the far end. It had been planted to potatoes in 1917, but had been in garden in 1918. Undoubtedly there was some soil infestation. This infestation is shown by the behavior of the control rows. The clean not-treated and the clean treated controls both showed some Rhizoctonia infected tubers in their progeny. The average for the clean controls not treated was 13.6 ± 1.38 percent, while that of the clean treated checks was 6.2 ± 1.6 percent of the tubers showing sclerotia. Most of this infection can probably be ascribed to organisms already in the soil when the tubers were planted.

On the whole the results were confirmatory of the previous findings in the laboratory. The results are shown in table IX.

Summary of Table IX: The hot formaldehyde treatments were as effective in controlling this disease as were the longer cold treatments with copper sulfate, mercuric chloride or formaldehyde. The best hot formaldehyde treatment was the one minute dip at 50°C. with a 1-120 solution followed by a one hour covering. Here only 6 percent of the progeny were infected. The best mercuric chloride treatment was two hours at 6-8°C., where 7 percent of the progeny were infected. The best cold formaldehyde treatment was the 1-120 solution for thirty minutes at 20°C. Five percent of the progeny showed sclerotia. The row treated with copper sulfate solution 3-400 at 6-8°C. for two hours, showed 13 percent of the progeny infected with sclerotia of the fungus.

The same facts that were found in the case of *Actinomyces scabies*, hold in the case of *Rhizoctonia solani*. The greater the dilution of the solution, the less its toxicity. For example, the formaldehyde solution 1-120 for thirty and one hundred and twenty minutes at 6-8°C. gave better control than the 1-240 solution for the same time and temperatures. The percent of sclerotia-infected tubers on the progeny of these rows was 11 percent on the 1-120 for thirty minutes and 20 percent on the 1-240. On the rows where the seed tubers were treated for one hundred and twenty minutes, the stronger solution had 12 percent of the tubers infected; the weaker 21 percent.

TABLE IX.—FIELD STUDIES ON THE CONTROL OF RHIZOCTONIA

Row No.	Condition of seed	Fungicide	Dilution	Temp. Degree Cent.	Time		Results	
					Dipped	Covered	Total yield ounces	Percent tubers showing sclerotia
1	Clean	$HgCl_2$	1-1000	6-8	90 mins.		590	7
2	Infected	None					828	40
3	Clean	None					520	7
4	Infected	CH_2O	1-120	55	1 min.	1 hr.	858	21
5	Infected	CH_2O	1-120	55	1 min.		986	13
6	Infected	$HgCl_2$	1-1000	6-8	90 mins.		1080	15
7	Infected	$HgCl_2$	1-1000	6-8	120 mins.		488	7
8	Infected	$HgCl_2$	1-1000	6-8	30 mins.		524	17
9	Infected	$HgCl_2$	1-1000	6-8	60 mins.		801	23
10	Infected	CH_2O	1-120	50	2 mins.	1 hr.	695	8
11	Infected	CH_2O	1-120	50	2 mins.		717	41
12	Clean	None					590	21
13	Clean	$HgCl_2$	1-1000	6-8	90 mins.		460	3
14	Infected	None					462	33
15	Infected	CH_2O	1-120	50	1 min.	½ hr.	589	17
16	Infected	CH_2O	1-120	50	1 min.	1 hr.	634	6
17	Infected	CH_2O	1-120	50	2 mins.	½ hr.	721	9
18	Infected	CH_2O	1-120	50	2 mins.	2 hrs.	704	19
19	Infected	CH_2O	1-120	50	2 mins.	5 hrs.	821	11
20	Infected	CH_2O	1-120	50	2 mins.	10 hrs.	584	20
21	Clean	None					367	16
22	Infected	None					444	33
23	Clean	$HgCl_2$	1-1000	6-8	90 mins.		404	1
24	Infected	CH_2O	1-60	48-50	2 mins.		656	22
25	Infected	CH_2O	1-60	48-50	2 mins.	1 hr.	751	10
26	Infected	CH_2O	1-60	48-50	2 mins.	5 hrs.	614	17
27	Infected	CH_2O	1-120	50	5 mins.		870	13
28	Soaked, Inf.	CH_2O	1-120	50	2 mins.	1 hr.	316	14
29	Soaked, Inf.	CH_2O	1-240	6-8	120 mins.		566	14
30	Soaked, Inf.	CH_2O	1-240	20	120 mins.		540	15
31	Clean	None					212	9
32	Infected	None					492	43
33	Clean	$HgCl_2$	1-1000	6-8	90 mins.		450	18
34	Inf., soak	$HgCl_2$	1-1000	6-8	30 mins.		731	39
35	Inf., soak	$HgCl_2$	1-1000	6-8	90 mins.		675	21
36	Inf., soak	CH_2O	1-240	6-8	30 mins.		1016	27
37	Inf., soak	CH_2O	1-240	20	30 mins.		438	13
38	Infected	CH_2O	1-120	20	120 mins.		630	33
39	Infected	CH_2O	1-120	20	30 mins.		488	5
40	Infected	$CuSO_4$	3-400	6-8	120 mins.		838	13
41	Clean	None					559	9
42	Clean	$HgCl_2$	1-1000	6-8	90 mins.		510	1
43	Infected	None					575	39
44	Infected	CH_2O	1-240	6-8	120 mins.		446	21
45	Infected	CH_2O	1-240	6-8	30 mins.		663	20
46	Infected	CH_2O	1-120	6-8	120 mins.		544	12
47	Infected	CH_2O	1-120	6-8	30 mins.		716	11
48	Clean	$HgCl_2$	1-1000	6-8	90 mins.		610	6
49	Infected	None					508	33
50	Clean	None					408	16

The effect of raising the temperature on the toxicity of formaldehyde was not brought out clearly in this series. Where direct comparisons can be made the results seem to indicate that the higher the temperature, the less the toxicity.

There are five places where direct comparison can be made as to relation of temperature to toxicity, viz., presoaked tubers treated with 1-240 solution of formaldehyde for thirty and one hundred and twenty minutes at 6-8°C. and 20°C., res-

pectively; infected tubers treated with 1-120 solution of formaldehyde for thirty and one hundred and twenty minutes at 6-8°C. and 20°C., respectively; and infected tubers treated with 1-120 formaldehyde solution for one minute and covered one hour. Both the thirty minute treatments at 6-8°C. show a greater percent of sclerotia on the progeny than the same treatment at 20°C. The percentages are 27 and 11 at 6-8°C. and 13 and 5 at 20°C., respectively. On the other hand, the three other treatments show a greater percentage of the disease with the progeny from the seed treated at the higher temperatures. In spite of these seeming inconsistencies, all the indirect evidence points to the fact that the toxicity of formaldehyde is increased by raising the temperature; otherwise, the control of the disease could not be so good with the short treatment, one, two, and five minutes at 50°C. It should be recalled that the mean of clean treated checks was 6.2 ± 1.6, which doubtless shows the amount of soil infection. In addition, this varied in different parts of the plot, which would cause irregularities in the treated rows.

The effect of covering the tubers after treatment is markedly shown in this series of experiments. In all cases but one (1-120 formaldehyde one minute, covered one hour), the rows where the seed had been covered after treatment showed a reduction of the disease in the progeny.

The advantages to be gained from presoaking the potatoes are not clear. In the five cases where comparison with unsoaked tubers is possible, but one case occurs in which the amount of disease on the progeny was diminished. The seed in this row was treated with 1-240 formaldehyde solution for one hundred and twenty minutes at 6-8°C. and gave 14 percent diseased tubers. The row having had its seed treated similarly without the soak before treatment, had 21 percent diseased tubers at harvest time.

Summary of Fig. 4: In fig. 4 the extent of control with the various treatments is shown graphically. The efficiency of all the seed treatments in controlling Rhizoctonia is quite apparent where the treated plots are compared with the checks. There should be little room for adverse criticism of seed treatment, irrespective of the method and formula used. We need only look at the length of the histographs labelled B, the infected untreated checks, and compare them with the remainder of the plot. The mean of the progeny showing sclerotia in untreated infected seed was 37.7 ± 1.1 percent. Only two plots in the treated series showed more sclerotia-bearing tubers at harvest; these were the plots where formaldehyde solution 1-120 for two minutes at 50°C. (fig. 4, No. 11), the mercuric chloride 1-1000 for thirty minutes at 6-8°C. (fig. 4, No. 34) where pre-

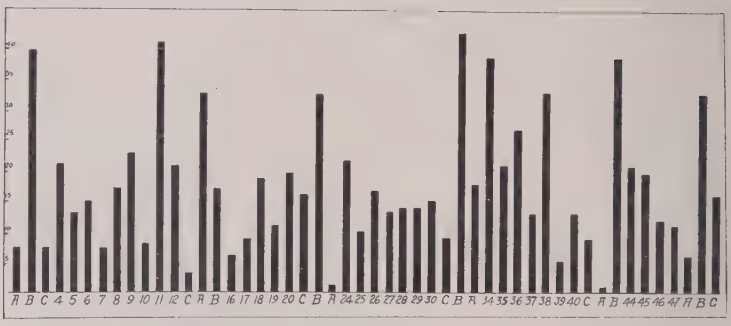

Fig. 4. The comparative value of seed treatment for black scurf in the field. The variation of soil and tuber infection is evident. The numbers below each histograph refer to the row number described in table IX. The height of the histograph indicates the percent of the progeny showing sclerotia. The check rows are lettered. A indicates the clean treated, B the infected untreated and C the clean untreated.

soaked tubers were used. The former gave 41 percent of tubers showing sclerotia, while the latter gave 39. Both of these percentages were below the worst check row, which gave 43 percent diseased tubers. The response of the clean treated and untreated will be discussed in a later paragraph.

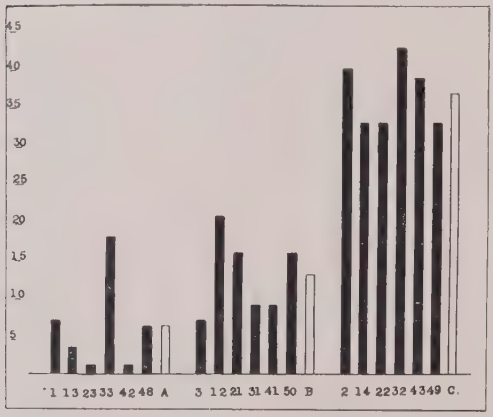

Fig. 5. The percent progeny showing the sclerotia of black scurf on the check rows with the calculated mean. The group A shows the clean treated checks; B the clean untreated and C the infected not treated. The figures below refer to the row number described in table IX. The height of the histograph gives the percent of progeny showing sclerotia.

Summary of Fig. 5: In fig. 5 the percent of diseased tubers in the check rows are brought together for comparison. The solid columns show the percent of diseased tubers in each row; the outlined columns the mean percent of all the rows having the same treatment. In group A, the clean treated (mercuric chloride 1-1000, one and one-half hours) checks, the mean is 6.2 ± 1.6 percent, with a dispersion

of 1 percent as the low in rows 23 and 42, and 18 percent as high in row 33. This dispersion is significant if we consider the infection on these rows as an index of the varying amounts of Rhizoctonia in the soil. Such a wide dispersion doubtless accounts for many of the discrepancies recorded earlier in the various treatments.

In group B, the untreated clean checks, the mean was 13.6± 1.38 percent, with a dispersion of 7 percent in row 3, to 21 percent in row 12. These checks indicate the amount of infection in the field, plus that carried on apparently clean seed. The difference between this mean and the percent of progeny showing sclerotia in the treated clean checks indicates the amount of infection found on apparently clean seed.

The infected untreated checks (group C) showed a mean of 37.7±1.1 percent. This group showed more uniform results than the other two. The lowest percent was 33, found three times in rows 14, 22 and 49. The greatest infection occurred in row 32, where 43 percent of the tubers showed Rhizoctonia. This high percentage infection is an index of sum of the organisms present in the soil and those carried on the surface of infected tubers. At this point it should be emphasized that clean treated and untreated checks are essential in any series of seed treatment experiments for the proper interpretation of the results. They measure the two variable factors, soil infestation and the inadequacy of surface disinfection.

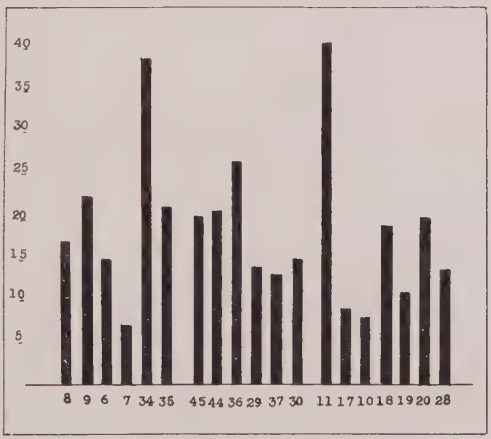

Fig. 6. Comparative value of different seed treatments on Rhizoctonia. In the group at the left are the rows treated with mercuric chloride solutions. The center group represents the cold formaldehyde treatments and the group at the right the hot formaldehyde treatments (50°C. for two minutes with or without covering). The figures at the bottoms of the columns refer to the number of the row described in table IX. The height of the columns represent the percent of the progeny in a row showing sclerotia of Rhizoctonia.

Summary of Fig. 6: It is worth while in passing to compare the efficiency of Rhizoctonia control of the two standard seed treatment methods and the hot formaldehyde method originated by the authors. As indi-

cated in the legend of fig. 6, they are grouped in three lots, beginning at the left with mercuric chloride, hot formaldehyde (50°C. for two minutes with and without covering) at the right and cold formaldehyde in the center. In each case there are wide variations. These are most striking in row 34 of the mercuric chloride and row 11 in the hot formaldehyde lots. Since the treatments are all different, it is impractical to find the mean for any of the three groups, but it is evident that as a whole the hot formaldehyde treatment is as good, if not better, than either of the other two standard treatments.

THE EFFECT OF FORMALDEHYDE AND BICHLORIDE ON THE GERMINATION OF SEED POTATOES

It was necessary not only to study the effect of high temperature on the pathogenes to be combated by seed treatment, but also the effect of the hot formaldehyde and mercuric chloride on the vitality of the seed.

Bolley (3) reports killing of seed potatoes treated in water at 55°C. for three minutes. He did not try formaldehyde solution. Melhus, Rosenbaum and Schultz (14) used a formaldehyde solution 1-120 at 46-50°C. for five minutes on the control of powdery scab (*Spongospora subterranea*). They did not report any injury to the germination. In a later paper, Melhus (12) reports using formaldehyde 1-120 at 48-50°C. for five minutes for the control of common scab without injury to the seed. However, when the temperature was raised to 55°C., some injury to germination occurred. As far as the authors are aware, no one has studied extensively the effect of hot fungicides on seed potatoes other than the instances cited above. This fact made it seem advisable to give some consideration to the effect of hot fungicides on seed potato germination. These studies were divided into two groups, those made in the greenhouse and those in the field.

GREENHOUSE GERMINATION EXPERIMENTS

In the greenhouse trials, the potatoes were treated by the usual methods described under laboratory studies. The tubers were cut to one or two eyes (buds) and placed in flats in the greenhouse. Later, observations were made on the time required for the sprouts to appear above the ground. The first of these experiments was made in the spring and summer of 1916 and the influence of the various temperatures, fungicides, and the time of exposure as related to the rest period of the tubers, was observed.

Summary of Table X: The results obtained in 1916 are

TABLE X.—INFLUENCE OF VARIOUS SEED TREATMENTS ON POTATO GERMINATION, 1916

Treatment	First Series—Planted May 18				Second Series Planted June 23			Third Series Planted July 20	
	Percent germination				Percent germination			Percent germination	
	May 28	May 30	June 2	June 4	July 5	July 12	July 15	July 27	July 31
CH_2O (1-240) 50° C. 5 mins.	0	0	66.6	100	8.3	100	100	50	83.3
CH_2O (1-120) 50° C.. 5 mins.	0	16.6	75	100	41.3	100	100	75	10.0
CH_2O (1-240) 2 hrs.	0	33.3	100	100	50	100	100	25	91.6
$HgCl_2$ (1-500) 50° C. 5 mins.	0	8.3	50	100	33.3	75	91.6	25	58.3
$HgCl_2$ (1-1000) 50° C. 5 mins.	0	0	33.3	100	58.3	100	100	33.3	91.6
$HgCl_2$ (1-1000) 2 hrs.	0	16.6	75	100	58.3	100	100	16.6	83.3
H_2O 50° C. 5 mins.	0	16.6	58.3	100	16.6	91.6	100	41.6	91.6
Check	8.3	33.3	66.6	100	58.3	100	100	33.3	100

shown in table X. The time the shoots broke thru the ground was considered germination. The seed, Early Ohio, was divided into three lots and these were treated on May 18, June 23, and July 20, respectively. In each series seven treatments were made and one lot of untreated tubers was added as a check. In the first series planted May 18, germination was retarded by the formaldehyde solution 1-240 for five minutes at 50°C., and by both the mercuric chloride treatments, 1-1000 and 1-500 at 50°C. In these three cases the germination on May 30 was 0, 8 1/3 and 0 percent respectively. None of the treatments materially hurt the stand on June 4, when the last count was made.

In the second series planted June 23, the difference in time of germination in the different experiments was not so marked as in the first series, but the mercuric chloride 1-500 for five minutes at 50°C., again caused the tubers in this lot to lag behind in their germination; so that on July 15, when the last count was made, only 91.66 percent had germinated. All the other treatments showed 100 percent germination at this time.

In the third series planted July 20, the experience of the two former series was repeated; the treatment with mercuric chloride 1-500 at 50°C. again showed the least germination when the final count was made.

When the three series are compared, it is noticeable that the injury was greater thruout the third series than it had been in either of the other two. It may be concluded from these facts that as the tubers advanced out of their rest period, they became more susceptible to the toxic action of the fungicide used. In no case did the formaldehyde at 50°C. for five minutes injure germination.

TABLE XI.—EFFECT OF FORMALDEHYDE 1-120, 50° C., ON GERMINATION OF SEED POTATOES

Treatment		Treated				Checks				
Time in minutes		No. days in flats	No. sets planted	No. grew	Percentage grew	Av. length stem, inches	No. sets planted	No. grew	Percentage grew	Av. length stem, inches
Dipped	Covered									
*	Dried	21	41	37	92.2	4	46	41	89.1	4
*	Dried	15	44	42	95.4	2	51	50	98.	2
*	15	21	46	41	89.1	4	41	34	83.	4
*	15	15	66	66	100.	2	49	37	75.5	2
*	30	15	52	35	67.3	2	55	53	96.5	2
*	60	13	59	55	93.2	2	74	68	92.	2
1	Dried	13	49	47	95.9	2.5	51	51	100.	2.5
1	15	24	61	61	100.	12	42	42	100.	12
1	30	24	34	32	94.1	10	19	19	100.	10
1	60	18	101	98	97.	2.5	95	94	98.9	3
2.5	Dried	24	57	55	96.5	10	57	57	100.	10
2.5	15	23	53	53	100.	10	51	49	96.1	10
2.5	30	20	59	56	94.9	4	60	58	96.6	4
2.5	30	13	84	81	97.6	1	83	71	85.5	1
2.5	60	19	71	65	91.5	3	72	72	100.	3
2.5	60	13	80	80	100.	1	98	96	97.9	1
5	Dried	24	59	58	98.3	6	72	65	90.2	6
5	15	18	77	63	81.8	2.5	77	77	100.	5
5	30	18	87	77	88.5	2.5	92	89	96.7	5
5	60	18	95	87	91.7	2.5	112	111	99.1	5

Summary of Table XI: In the common scab experiments, after the isolation of *Actinomyces scabies* from the tubers, the potatoes were cut to one eye and the pieces from the treated and untreated halves were planted in flats in the greenhouse. After the stems had come thru the ground, the sets were dug and the number that grew counted. The average length of stem was also noted. The results are shown in table XI.

A comparison of the treated and check lots in each case shows a rather wide variation, ranging from 75.5 to 100 percent in the checks and 69.3 to 100 percent in the treated seed. None of the treatments at 50°C. for the one and two and one-half minutes show any significant difference in length of stems or in percent that grew. Where the treatment was lengthened to five minutes and covered fifteen, thirty and sixty minutes, there was apparently a delay, which is indicated by the slower growth, altho there is no significant difference in the percent germination. The treated seed had an average stem length of two and one-half inches and the checks of five inches. Whether or not this difference is an important indicator of injury will receive consideration again in the discussion of the field data.

Summary of Table XII: With these results in view, a study of the influence of formaldehyde solutions on the germination was repeated. Seed potatoes of the variety Early Ohio that were well out of the rest period were treated with formaldehyde

* Dip was momentary.

solutions of strengths varying from 1-60 to 1-240. The tubers were exposed in each solution for two and five minutes at 50°C. and for two minutes at 54°C. In all cases the tubers were covered for one hour after treatment. Checks with water at 50°C., at 54°C., and untreated, were also made. After treatment the tubers were cut to one eye and placed in flats in the greenhouse. The results are recorded in table XII.

From these results we find that the strongest solution of formaldehyde that may be recommended is 1-120, injury shown by delayed germination occurring in both the 1-60 and 1-100 dilutions. The maximum time of exposure also is approximately five minutes, since we find occasional injury in the five minute exposures with the stronger formaldehyde solutions. At 54°C. in water or formaldehyde solutions, some injury occurred. The effect of the injury on the tubers appeared in two ways, by retardation of germination, which influenced the length of stem, and by the killing of the buds. Thus, with formaldehyde solution 1-60 for two minutes at 50°C., the germination was not retarded, but only 94.6 percent of the buds grew. With the same solution for five minutes, both the growth was retarded, as shown by the shorter stem length at the time the counts were made (1 inch), and the lowered percent alive, (89 percent). The best growth occurred with the 1-240 solution for two minutes at 50°C., altho there was but little difference between this and the 1-120 solution at 50°C. for two minutes.

FIELD STUDIES ON SEED GERMINATION

The influence of seed disinfectants was studied not only under greenhouse conditions, but also in the field. It was realized at the outset that greenhouse conditions could serve only as an

TABLE XII.—EFFECT OF FORMALDEHYDE SOLUTIONS ON THE GERMINATION OF POTATO TUBERS IN THE GREENHOUSE

Row No.	Fungicide	Dilution	Temp. Degree Cent.	Time (min.)	Covered (hours)	Percent grew inches		
						2	1½	1
1	CH_2O	1-60	50	2	1	94.6		
2	CH_2O	1-60	50	5	1			89
3	CH_2O	1-60	54	2	1		95	
4	CH_2O	1-100	50	2	1		95	
5	CH_2O	1-100	50	5	1	83.		
6	CH_2O	1-100	54	2	1		94	
7	CH_2O	1-120	50	2	1	99.		
8	CH_2O	1-120	50	5	1	96.		
9	CH_2O	1-120	54	2	1		96	
10	CH_2O	1-240	50	2	1	99.		
11	CH_2O	1-240	50	5	1	100.		
12	CH_2O	1-240	54	2	1	97.		
13	H_2O		50	5	1	96.		
14	H_2O		54	5	1			99
15	H_2O		54	10	1			96
16	Check					99.		

indicator and not as a measure of the responses under field conditions. The field trials were begun in 1916 and continued to the present time, except for 1918, when the plots were destroyed by excessive spring rains and hail.

Summary of Table XIII: In the spring of 1916 Early Ohio seed potatoes just out of the rest period were treated by the eight different methods shown in table XIII. Two lots were held as checks. The potatoes were planted on an irregular piece of ground tending to be low at one end. The seed after treatment was cut in the usual manner and planted in four rod-rows, 12 inches between the hills.

It is significant that in none of the treatments did all the sets grow and in the two lots of checks, the stand was 77 and 84.3 percent respectively. The fact that all the seed pieces did not grow was probably due to a variety of factors, chiefly soil conditions and imperfect cutting (one to two eyes per set).

The double strength of corrosive sublimate injured the stand; only 68.4 percent of the sets planted grew. Likewise the temperatures of 58-60°C. cut down the stand very materially with both formaldehyde and corrosive sublimate solutions. With water at this temperature (58-60°C.), the stand was but slightly reduced below the untreated checks. While the yield per hill was determined in each treatment, it is probably of relatively little significance, due to the small number of hills in each experiment. From these data, therefore, we may conclude that a temperature of 58-60°C. is unsafe for treating potatoes, and corrosive sublimate of the strength 1-1000 is as strong as can be used in practice.

Summary of Table XIV: The influence of the various seed treatments on the stand was studied further in 1917 and the

TABLE XIII.—EFFECT OF VARIOUS METHODS OF SEED TREATMENT UPON HEALTHY SEED POTATOES

Variety	Fungicide	Dilution	Temp. Degree Cent.	Time	Sets planted	Percent germination		Av. yield per hill, oz.	
						June 12	July 31		
E. Ohio	Check				139	76.1	77.	4.45	
E. Ohio	$HgCl_2$	1-500	47-50	5 mins.	168	88.1	68.4	3.1	
E. Ohio	CH_2O	1-120	50	5 mins.	136	82.3	86.8	3.8	
E. Ohio	$HgCl_2$	1-500	58-60	5 mins.	137	16.05	32.1	2.3	+
E. Ohio	CH_2O	1-120	58-60	5 mins.	141	24.1	29.8	4.	
E. Ohio	H_2O		58-60	5 mins.	218	54.5	78.9	3.5	+
E. Ohio	CH_2O	1-120	47-50	5 mins.	131	54.1	75.5	6.5	+ +
E. Ohio	$HgCl_2$	1-1000	50	5 mins.	727	79.8	80.3	5.3	+ +
E. Ohio	CH_2O	1-240		2 hrs.	183	91.8	96.1	3.9	
E. Ohio	Check				810	82.2	84.3	5.6	+

TABLE XIV.—EFFECT OF VARIOUS METHODS OF SEED TREATMENT UPON THE GERMINATION OF POTATO TUBERS AT ELLSWORTH

Seed		Fungicide	Dilution	Temp. Degrees Cent.	Time	No. sets planted	Percent germination			Av. yield per hill oz.
Source	Variety						June 3	July 2	July 5	
Maine	Cobblers	CH_2O	1-120	50-55	5 mins.	351	77.2	90.8	92.	9.
Maine	Cobblers	Check				393	87.2	82.6	88.3	9.
Iowa	Cobblers	CH_2O	1-120	47-50	5 mins.	335	88.3	88.6	93.4	9.6
Iowa	Cobblers	CH_2O	1-120	cold	2 hrs.	363	95.8	92.8	88.5	10.
Iowa	Cobblers	Check				343	92.4	91.8	96.5	8.8
Iowa	Cobblers	$HgCl_2$	1-1000	45-50	5 mins.	370	84.05	88.1	91.3	8.9
Iowa	Rurals	CH_2O	1-480	50	5 mins.	139	82.7	89.9	97.1	10.5
Iowa	Rurals	Check				216	66.6	72.2	72.7	9.1
Iowa	Rurals	CH_2O	1-120	45-50	5 mins.	263	63.1	88.9	92.8	11.5
Iowa	Rurals	Check				343	84.5	81.2	82.8	10.5
Iowa	Cobblers scabby	CH_2O	1-120	54-57	2 mins.	393	63.3	75.3	79.1	6.9
Iowa	Cobblers clean	CH_2O	1-120	cold	2 hrs.	363	92.5	90.	88.6	10.
Iowa	Cobblers scabby	CH_2O	1-120	50	5 mins.	390	87.9	83.3	97.5	7.4
Iowa	Cobblers scabby	Check				335	88.0	89.	91.	4.
Iowa	Rurals	Check	1-120	50	5 mins.	343	92.	92.	96.	8.8
Iowa	Rurals scabby	CH_2O				370	83.8	88.1	91.3	6.7
Iowa	Rurals scabby	Check				390	87.6	80.7	81.5	5.9
Iowa	R. clean	CH_2O	1-120	50	5 mins.	139	83.4	89.9	97.1	10.6
Iowa	R. clean	Check				216	66.7	72.7	72.7	9.1

data is recorded in table XIV. This time Irish Cobblers from two sources and the variety Rural New Yorker were used. The Irish Cobblers were obtained from northern Maine thru the kindness of Dr. E. S. Schultz of the office of Cotton and Truck Diseases. None of this seed lot had tubers that came from hills infected with black leg. The infected hills had been rogued out. The other lot of Irish Cobblers were Iowa grown, of smaller size and further along in the rest period. The Rural New Yorkers were grown the previous year on the Station plots by Professor A. T. Erwin. This seed was smooth and quite dormant; when treated, the sprouts were just visible. As in the previous experiment, the seed was cut to one or two eyes and planted early in May at Ellsworth, Iowa. The mean percentage of germination in the seven checks was 83.6 and in the twelve treatments it ranged from 79.1 to 97.5. The poorest germination was secured where the scabby seed was treated with formaldehyde 1-120 at 54-57°C. for two minutes. As brought out in tables XII and XIII, temperatures above 55°C. begin to show some injury. The source of seed, variety and general vigor seems to have no effect on the percentage of germination. This series of experiments was planted in an old hog pasture that had been seeded down for 18 years. Altho the yield which is

given in each case tends to show that the treated seed yields the highest, it cannot be accepted as of much consequence, due to the small number of plants. It does indicate, however, that there probably is no decrease in the yield.

Summary of Table XV: The effect of seed treatment on stand was observed again in 1919 in the field. Vaious strengths of formaldehyde, temperatures and varying lengths of exposures were made. The tubers were planted in two plots. One plot was planted April 19 and notes made on the germination on May 20 and June 20 respectively. In the other plot the tubers were planted May 10 and observations made on May 31 and June 18. Two hundred pieces cut to one eye were planted in each row. The results are given in table XV.

In Plot 1 there was but little injury to germination in any of the treatments. Where formaldehyde 1-60 was used at 50°C. for two minutes, some injury occurred. The 1-120 formaldehyde showed no injury at the same temperature, which must be due to the difference in concentration of the solution.

In Plot 2 no injury occurred even with the 1-60 formaldehyde solution at 50°C. for two minutes.

THE STABILITY OF FORMALDEHYDE WHEN USED AS A FUNGICIDE

In connection with these studies on the fungicidal effect of formaldehyde, the question of its stability in a dilute solution came up for consideration. When it is used in practice for seed treatment purposes, its temperature is raised for several hours at a time. We need to consider not only the influence of temperature, but also the effect of evaporation and the presence of a considerable quantity of organic and inorganic material in the solution. Will it maintain its strengh under the above conditions, or will its concentration change?

STUDIES ON DILUTE SOLUTIONS

The concentrations of the solutions were determined by the iodometric method described by Romijn (18) using Merck's chemicals, but not standardized glassware. This fact may well have introduced an error, but considering that the chief aim of the experiments was to measure the changes in the concentration rather than to make an exact volumetric determination of the amount of formaldehyde present, this error was hardly sufficient to vitiate the results, since the same glassware was used thruout the work.

Experiments were made first to determine whether formaldehyde solutions changed in concentration when exposed to

evaporation at room temperature. Dilute solutions comparable to those used in practice were made up from commercial formaldehyde containing 38.45 grams of formaldehyde per hundred cubic centimeters.

Two solutions were made up; D and E. In D a solution of formaldehyde 1-100 was prepared and heated to 50°C. eight different times and then titrated to determine the strength. At the end of this period it was found to contain .4045 grams of formaldehyde in 100 cc. Another solution, E, was prepared and heated slowly to 80°C., and titrated; this solution then contained .37 grams of formaldehyde per 100 cc. Heating dilute solutions of formaldehyde up to 80°C. does not seem to materially weaken it.

TABLE XV.—EFFECT OF FORMALDEHYDE ON THE GERMINATION OF POTATO TUBERS, 1919

Condition of seed	Fungicide	Dilution	Temp. degree Cent.	Time		Percent stand			
						Plot 1		Plot 2	
				Dipped minutes	Covered hours	May 20	June 20	May 31	June 18
Clean	Check					63.5	92.5	72.	80.5
Infected	Check					63.5	87.5	71.5	93.
Clean	$HgCl_2$	1-1000	6-8	90		77.0	86.5	91.5	96.5
Infected	CH_2O	1-120	6-8	30		80.5	94.	81.	92.5
Infected	CH_2O	1-120	6-8	60		70.	98.		
Infected	CH_2O	1-120	6-8	120		74.5	97.5	69.5	83.
Infected	CH_2O	1-120	20	30		80.	99.	83.	94.5
Infected	CH_2O	1-120	20	120		77.5	99.5	81.	98.
Clean	Check					79.	99.	82.	90.5
Infected	Check					73.	94.5	78.5	92.5
Clean	$HgCl_2$	1-1000	6-8	90		71.5	96.5	85.5	94.5
Infected	CH_2O	1-120	48-50	5		70.	90.5	87.5	99.
Infected	CH_2O	1-120	48-50	2½		58.	95.	82.	94.5
Infected	CH_2O	1-60	48-50	2		79.	84.5	86.	97.
Infected	CH_2O	1-60	48-50	2	1	59.5	85.5	87.	97.5
Infected	CH_2O	1-60	48-50	2	5	58.5	85.0	88.	96.5
Clean	Check					63.5	96.5	86.5	95.
Infected	Check					60.0	92.5	73.	93.5
Clean	$HgCl_2$	1-1000	6-8	90		65.	92.5	82.5	95.
Infected	CH_2O	1-120	48-50	2	1	68.5	93.5	87.	90.
Infected	CH_2O	1-120	48-50	2	2	67.5	92.	89.	96.5
Infected	CH_2O	1-120	48-50	2	5	65.	93.	89.	97.5
Infected	CH_2O	1-120	48-50	2	10	73.5	94.5	87.	98.
Clean	Check					67.	86.	83.	88.5
Infected	Check					64.	92.	76.5	98.
Clean	$HgCl_2$	1-1000	6-8	90		65.	93.5	86.	94.
Inf. soak	CH_2O	1-120	48-50	2	1	65.	89.5	75.5	96.
Inf. soak	CH_2O	1-240	6-8	120		55.	93.5	83.5	98.
Clean	Check					67.5	96.5	83.5	95.5
Infected	Check					68.5	91.	63.	94.
Clean	$HgCl_2$	1-1000	6-8	90		77.5	97.	67.5	79.5
Infected	$CuSO_4$	3-400	6-8	120		55.	90.	80.	94.
Infected	$HgCl_2$	1-1000	6-8	30		65.	93.	86.	97.
Infected	$HgCl_2$	1-1000	6-8	90		75.	97.5	86.5	96.5
Infected	CH_2O	1-240	6-8	30		58.	83.5	87.5	97.5
Infected	CH_2O	1-240	6-8	120		76.5	100.	88.5	84.5
Clean	Check					74.5	99.	85.5	100.
Infected	Check					59.5	96.	74.5	93.
Clean	$HgCl_2$	1-1000	6-8	90		62.	93.	80.	86.5

TABLE XVI.—EFFECT OF STANDING ON THE STRENGTH OF FORMALDEHYDE SOLUTION

Solution	Dilution	Time of standing	Grams CH_2O per 100 cc.	Approximate dilution
A	1 cc. CH_2O in 100 cc. H_2O	0	0.3845	
		26 days	0.400	
B	1 cc. CH_2O in 250 cc. H_2O	0	0.142	
		26 days	0.129	
C	1 cc. CH_2O in 120 cc. H_2O	0	0.358	1-116.6
		12 hrs.	0.352	1-118.6
		24 hrs.	0.364	1-114.7
		78 hrs.	0.375	1-111.4

Summary of Table XVI: It is also interesting to know whether the dilute solution weakens when standing in an open container at room temperature. Two solutions were made up, one A, one part formaldehyde in 100 parts of water, and the other B, one part in 250 parts of water. These were allowed to stand in the laboratory for twenty-six days at room temperature. When titrated the solutions showed the following strengths: .4 grams, and .129 grams per 100 cc. respectively. The stronger solutions became a trifle stronger and the weaker one became slightly weaker, dropping off .013 percent. In C, the dilution was determined after 12, 24 and 72 hours, respectively. In this case the solution increased in concentration .023 grams per 100 cc. The data in hand suggests that the formaldehyde solutions used changed strength only slightly on being exposed at room temperature in an open container for twenty-six days. In all the three solutions the titrations were not made until after half of the original volume of solution had evaporated. It would seem that where dilute solutions are exposed to evaporation, the concentration changes slowly, with a tendency to become slightly more concentrated. The increase in concentration is apparently not very great and in seed treatment experiments would not seem to be very significant.

Summary of Table XVII: After these preliminary experiments, solutions of 1 cc. to 120 cc. of water, and 1 cc. to 240 of water were made up and titrated. The commercial formaldehyde used in these tests titrated 39.3 percent. Later they were heated to 50°C., or to the boiling point, and held at these temperatures for varying lengths of time. The results of the titrations are brought together in table XVII.

The data show that when dilute solutions of formaldehyde are heated to 50°C. and held for different lengths of time, there is no appreciable change. A solution of approximately 1-120 dilution, after being held at 50°C. for one hour, showed only

TABLE XVII.—CHANGES IN CONCENTRATION OF FORMALDEHYDE SOLUTIONS HELD AT VARIOUS TEMPERATURES FOR DIFFERENT LENGTHS OF TIME IN THE LABORATORY

Formaldehyde solution						
Sample No.	Approximate concentration	Temp.	Time in minutes	Ave no. cc. n/10 $Na_2S_2O_3 + 5\ H_2O$	Grams CH_2O per 100 cc. solution	Approximate dilution
1	1-120	cold	0	.9	0.307	1-128
2	1-120	50° C.	15	.91	0.306	1-128.1
3	1-120	50° C.	30	1.08	0.294	1-133
4	1-120	50° C.	60	1.	0.3	1-131
1	1-120	boiling	0	.8	0.315	1-124.8
2	1-120	boiling	5	.75	0.318	1-123.2
3	1-120	boiling	10	.8	0.315	1-124.8
4	1-120	boiling	15	.908	0.307	1-128
1	1-240	cold	0	2.46	0.19	1-206.8
2	1-240	50° C.	0	2.6	0.18	1-218.3
3	1-240	50° C.	15	2.73	0.17	1-231.3
4	1-240	50° C.	30	2.63	0.177	1-222
5	1-240	50° C.	60	2.7	0.172	1-226
1	1-240	cold	0	2.51	0.186	1-211.3
2	1-240	boiling		2.53	0.185	1-212.4
3	1-240	boiling	15	2.63	0.177	1-222
4	1-240	boiling	30	2.58	0.181	1-217.1
1*	1-200	cold	0	3.44	0.309	1-199.3
2	1-200	boiling	0	3.31	0.228	1-183.1
3	1-200	boiling	15	3.38	0.218	1-191.1
4	1-200	boiling	30	3.33	0.225	1-185.6
5	1-200	boiling	45	3.25	0.237	1-176.2
6	1-200	boiling	60	3.48	0.203	1-205.7
7	1-200	boiling	75	3.41	0.213	1-196
8	1-200	boiling	90	3.50	0.2	1-208.3
1*	1-120	cold	0	2.38	0.368	1-113.4
2	1-120	50° C.	0	2.38	0.368	1-113.4
3	1-120	50° C.	15	2.41	0.363	1-115
4	1-120	50° C.	30	2.44	0.359	1-116.3
5	1-120	50° C.	60	2.39	0.366	1-114.1
6	1-120	50° C.	90	2.34	0.374	1-111.6
7	1-120	50° C.	120	2.48	0.363	1-115
8	1-120	50° C.	180	2.51	0.373	1-112.2
9	1-120	50° C.	300	2.53	0.37	1-112.8

.00007 of a gram less formaldehyde per cc. A solution of the same dilution after being boiled for fifteen minutes showed only .00008 of a gram less per cc. Slight fluctuations were observed, but in general the strength of the solution remained approximately the same thruout the heating or boiling, as the case might be.

Summary of Table XVIII: Since the strength of formaldehyde solutions does not materially diminish on account of evaporation at room temperatures or when held at higher temperatures (50°C.) five hours, the next step was to determine whether or not the fungicide was taken out by the dirt and potatoes in the treatments. Opportunity was offered to determine this ques-

* The formaldehyde solution used was determined to be 41.76 percent.

TABLE XVIII.—CHANGES IN CONCENTRATION OF FORMALDEHYDE SOLUTIONS DURING THE SEED TREATMENT OF POTATOES WHEN STEAM WAS USED AS A SOURCE OF HEAT

No. lot	Sample number	Temp. Degrees Cent.	Time	No. bushels treated	Grams CH_2O per 100 cc. solution	Dilution of CH_2O
1	1	45-50	0	0	0.3245	1-120
	2	45-50	35 mins.	35	0.282	1-138
	3	45-50	2½ hrs.	105	0.224	1-174 (1)
	6	45-50	17½ hrs.	185	0.214	1-182
	7	45-50	21½ hrs.	345	0.18	1-216
2	1	48-50		20	0.317	1-122.4
	2	48-50		41	0.316	1-122.9
	3	48-50			0.300	1-129 (2)
	4	48-50		61	0.310	1-125.2
	5	48-50			0.284	1-136.6 (3)
	6	48-50		81	0.286	1-135.7
	7	48-50			0.276	1-140.6 (4)
	8	48-50		101	0.269	1-144.3
	9	48-50		121	0.250	1-155.3
3	1			0	0.334	1-128.4
	2			65	0.295	1-145.3
	3			100	0.274	1-156.5 (5)

(1) The strength of the solution after 35 bushels were treated was 1-138. At this point 15 gallons of water were added making the solution 1-174.
(2) At this point 40 gallons of stock solution of the original dilution were added.
(3) At this point 15 gallons of stock solution of the original dilution were added.
(4) At this point 15 gallons of stock solution of the original dilution were added.
(5) Twenty gallons of stock solution were added before the last 35 bushels were treated.

tion in both 1918 and 1919, when large quantities of potatoes were treated for seed purposes.

The treatments were made in a tank containing 200 gallons of solution. The source of steam was a small, upright stationary steam boiler in Lot 1 on the Sam Kennedy farm, and the college heating plant in Lots 2 and 3. In the former case there was considerable water of condensation added to the original solution, due to the small size of the boiler.

In Lot 1, 345 bushels were treated and samples of the solution were collected at intervals and titrated. Two hundred gallons of 1-120 concentration were made up in a large wooden tank. When heated to 50°C., it showed .3245 grams of formaldehyde per 100 cc.; after treating 35 bushels it showed .282 grams; 105 bushels, .224 grams; 185 bushels, .214 grams, and 345 bushels, .18 grams of formaldehyde per 100 cc. The sudden drop in sample 3 is due to the addition of about 15 gallons of water by mistake just before sample 3 was taken. The diminution of the original solution caused by wetting of the tubers made it necessary to replenish the stock solution in the seed treatment operation. A solution of the original concentration was used for this purpose. The average loss per cc. in concen-

tration per 100 bushels in the three lots studied, was 0.00069, 0.0007, and 0.0006, respectively.

These averages were obtained by using only those concentrations where no addition of solution was made between the two concentrations chosen. This method of choice was adopted to avoid the error introduced by the mixture of the two solutions of different concentrations. The rate of change of concentration is quite uniform thruout. The data show that in actual practice, where steam is used as a source of heat the solution becomes more dilute and must be corrected to maintain the original dilution. The fact that the solution becomes more dilute may be due to one or two factors, either the condensation water from the steam or the absorption of formaldehyde by the dirt and surfaces of the seed tubers. The former explanation seems to be the more justifiable, for steam surely tends to add a considerable amount of water in the process of raising and maintaining a solution at a temperature of 50°C. where tubers of a considerably lower temperature are being constantly dipped. Whether steam is the chief cause of the dilution of the solutions is shown in the next set of data, where the solution was not heated by steam but by a small heater set into the tank.

Summary of Table XIX: In these experiments, seed potatoes were treated on a commercial scale, Lots 1 and 2 at Ames, and Lot 3 at Nevada, Iowa. The temperature was held between 48 and 50°C. by means of the heater described by Melhus and Gilman (13). The solution decreased in the tank due to loss

TABLE XIX.—CHANGES IN FORMALDEHYDE SOLUTIONS DURING TREATMENT OF POTATOES WHEN A TANK HEATER WAS USED AS A SOURCE OF HEAT

No. lot	Sample number	Temp.	No. bu. treated	Grams CH_2O per 100 cc. solution	Dilution of CH_2O
1	1	cold	0	0.315	1-121.9
	2	50° C.	45	0.343	1-111.7
	3	50° C.	60	0.330	1-116.0 (1)
2	1	cold	0	0.363	1-105.7
	2	50° C.	20	0.366	1-104.6
	3	50° C.	50	0.375	1-102.4 (2)
3	1	cold	0	0.322	1-138
	2	50° C.	20	0.319	1-139.3
	3	50° C.	40	0.300	1-148.4
	4	50° C.		0.312	1-142.6 (3)
	5	50° C.	65	0.325	1-136.7
	6	50° C.	90	0.310	1-143.4
	7	50° C.		0.307	1-144.8 (4)
	8	50° C.	115	0.306	1-145.5
	9	50° C.	125	0.306	1-145.5

(1) Fifteen gallons of stock solution were added before the last 15 bushels were treated.
(2) Thirteen and one-half gallons of stock solution were added before the last 30 bushels were treated.
(3) Solution stood from Saturday until Tuesday.
(4) Thirty gallons of stock solution were added and sample taken.

of the same on the tubers and in other ways incident to the practice of seed treatment.

It should be noted that the concentration of the solution changed relatively little. In Lot 1, after treating 45 bushels there was an increase in concentration of .028 grams formaldehyde per cc. At this point some of the reserve stock solution had to be added to maintain the original volume. There was a similar slight increase in concentration in Lot 2 of .003 grams formaldehyde per 100 cc. after treating 100 bushels. In the two above lots the concentration increased, but in Lot 3 it became slightly weaker thruout the experiment. In the first 20 bushels treated, it changed .003 grams formaldehyde per 100 cc. Between 65 and 90 bushel titrations, there was also a loss of .015 grams and in the last 35 bushels treated it changed only .001 grams formaldehyde per 100 cc.

This rather limited data suggests that when potatoes are treated in a dilute solution held at 48-50°C. by means of a heater, the loss in concentration is not uniform nor very large. It is possible that the amount of dirt on the seed may influence the rate of loss of formaldehyde concentration and that a certain amount of the disinfectant is absorbed by the surface of the tubers. It is quite obvious that the rate loss of concentration is not as great as where steam was introduced into the solution. This difference is doubtless due to condensation water.

The concentration of dilute formaldehyde solutions (1-120 and 1-250) does not change due to evaporation at room temperature. Raising the temperature to 50°C. and holding it at this temperature for fifteen to sixty minutes did not change the concentration of dilute solutions.

When steam is used to heat the dilute solutions in seed treatment experiments, the concentration changes, due to the addition of water of condensation. The data at hand show that the average loss in concentration per cc. per 100 bushels in the three lots studied was 0.00069, 0.0007, and 0.0006 grams. From these figures it may be calculated that for each 100 bushels treated, 660 cc. of the formaldehyde (40 percent) solution should be added to each 100 gallons of the solution. The amount of dilution is probably proportional to the amount of formaldehyde solution to be heated and the surface temperature of the tubers to be treated.

Where a heater is used to heat the solution, there is also a slight change in concentration. This is probably due to a certain amount of formaldehyde being taken up by absorption in the dirt and on the surface of the tubers treated. In two of the three series in which a heater was used, the solution increased in concentration, while in the third it decreased.

SUMMARY

The studies reported in this bulletin deal with the toxic action of formaldehyde and other surface disinfectants, as manifested in potato seed treatment. The organisms utilized were *Actinomyces scabies* and *Rhizoctonia solani*. Not all common scab sori contain viable organisms.

Surface disinfection with formaldehyde for the control of scab was more complete at 20°C. than at lower temperatures. Formaldehyde at 48-50°C. for short periods of time was as toxic as mercuric chloride and formaldehyde of the standard formulae. Covering after treatment with hot formaldehyde 50°C., facilitates disinfection. Increasing the concentration increases the toxicity of this chemical to both scab and scurf. Surface disinfection is seldom complete, which introduces a variable factor into field treatment experiments.

The extent of soil infestation is best measured in clean treated seed. Untreated clean seed in 1919 carried to the field sufficient number of Rhizoctonia sclerotia to cause 6 percent infection on the progeny. All of the methods of seed treatment reduced the percentage of infection over the checks, showing that seed treatment is worth while from a practical standpoint.

It was found that the germination of seed tubers was injured with mercuric chloride 1-500 and formaldehyde 1-120, when the temperature was raised above 55°C. for more than five minutes. No injury was induced by formaldehyde 1-120 at 50°C. for two and one-half minutes, followed by covering one hour.

Laboratory methods were devised by means of which the value of a given seed treatment can be predicted without the necessity of field trials. The laboratory methods were confirmed in the field.

The effect of standing, heating and treating of potatoes on dilute formaldehyde solutions was studied. The data obtained suggests that formaldehyde solutions used changed strength only slightly on being exposed at room temperature in an open container for twenty-six days. Dilute solutions of formaldehyde heated to 50°C. and held at this temperature from five to sixty minutes showed no appreciable change in concentration.

Formaldehyde solutions lose some of their concentration when potatoes are treated at 48-50°C. The loss in concentration was greater when steam was used as a source of heat than when a heater, such as was described by the authors in a previous publication, was used. The greater loss is probably due to the condensation of the steam in the solution. With the heater, the loss in concentration of solution was very slight.

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